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THE EFFECTIVENESS OF ONLINE AND BLENDED LEARNING FROM SCHOOLS: A SYSTEMATIC REVIEW

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Executive Summary

This systematic analysis examines the research evidence on Online and Blended Learning **from** schools (rather than **in** schools). It is particularly relevant at a time when schools have been forced by the covid-19 pandemic to implement some of these, as pupils have been unable to attend school. In addition, the review investigates Educational Games, Computer Supported Cooperative Learning (CSCL) and Computer Assisted Instruction (CAI), which have been largely used in schools but have the potential to be used outside school. Web-based learning **in** school was included in CAI.

Eight different research databases were searched. Studies not relating to schools, dated before 2000, not in English, without data and duplicates were removed. Remaining were 1355 studies from all over the world: Online studies 134 (7%), Blended 232 (13%), CSCL 129 (7%), Games 488 (26%), and CAI 865 (47%).

Overall, digital technology was found more effective than Traditional Instruction in 85% of studies, while 8% found it the same and only 3% found it worse.

Blended Learning was considerably more effective than Online Learning (83% of studies more effective than Traditional Instruction or other comparator conditions compared to 74%). Of the other conditions, (CAI) was the most effective (91%), with Games and CSCL (both 81%) coming after Blended Learning, but most of these had taken place in school.

Previous reviews of the research evidence numbered 144: Online 19, Blended 20, Games 56, CSCL 14 and CAI 35. Unfortunately, 81% of these covered primary, secondary and higher education together and did not discriminate between sectors. Nonetheless, such indicators of magnitude of effect as were available suggested CAI was the most effective, followed by Blended Learning, Games and CSCL, followed by Online Learning – similar to the findings for all separate studies.

Regarding school sector, Primary and Early Years/Kindergarten both were 87% Better than Traditional Instruction, while Secondary/High came next with 80%, Primary/Secondary next and last was Middle Schools with 73%.

Regarding Subjects, Science and Maths were the most popular, then Thinking, Reading, English as a Foreign Language (EFL), Humanities, Health, STEM, Writing, English, Arts/Music and Foreign Languages in that order.

However, EFL interventions were the most effective, then Writing and STEM, Thinking, Arts/Music, Humanities, Health and Science, Reading and Math, Foreign Languages and English. Thus, the most popular subjects were by no means those where the greatest effectiveness was evident.

Regarding gender, Females were Better in 27 cases (39%), Males and Females were equal in 36 cases (52%), and Males Better in only 6 (9%). Thus, overall, females did better.

Four categories of studies showed high effectiveness (higher than the average for all papers in all studies): HiLo studies (mostly “low ability” children) (total n=76, 92% Better); Socio-Emotional Functioning studies (mostly focused on self-efficacy) (225, 91%); Second Language Learner studies (mainly English as a Foreign Language learners) (69, 90%); Non-English-Speaking Educational Context studies (in a country which did not have English as its first language) (329, 89%).

Two categories showed equal effectiveness (equal to the average for all papers in all studies): Hospitalised or Sick at Home studies (7, 86%) and Rural studies (29, 85%).

Five categories showed lower effectiveness (lower than the average for all papers in all studies). The first was Special Educational Needs (SEN) or Disability (n=89, 80%) (although this was not much lower than the average for all students). Within this, Deaf and Hard of Hearing (100%), Down Syndrome (100%), Writing Difficulty (100%), Attention Deficit and Hyperactivity Disorder (90%), Learning Disability (87%) and Autistic Spectrum Disorder (86%) all scored higher than the average for all students. The others were: Gifted studies (n=10, 80%); Psychological Well-Being (17, 79%); Disadvantaged (46, 79%) (not much lower than the average for all students) and Ethnic Minorities (32, 78%) (not much lower than the average for all students). However, all these categories were effective to different degrees.

Thus, Blended Learning was more effective than Online Learning, although both were effective but to different degrees, and Online Learning may be the only option for students remote from school and those unable to attend school owing to pandemics or other causes. CAI was more effective than either, but much of CAI was in school, and it cannot be assumed that it would be as effective if delivered to homes. The effectiveness of Games and CSCL fell somewhere between Blended and Online Learning, but again much of this was in school, and it cannot be assumed that it would be as effective if delivered elsewhere. The limitations and strengths of the research were discussed and conclusions offered in relation to the research questions. The implications for practitioners, policy-makers and future researchers were outlined.

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The Effectiveness of Online and Blended Learning from Schools: A Systematic Review

This systematic literature review starts with an Introduction which outlines the urgent need for the study, in view of the heightened demand created by the corona-virus pandemic. It notes that many of the studies on online and blended learning have been conducted in higher education. However, the present review of digital learning **from schools** since 2000 encompassed 1355 studies, so clearly there is a good deal of research on this also. In addition, the review investigates Educational Games, Computer Supported Cooperative Learning (CSCL) and Computer Assisted Instruction (CAI), which are mostly used in school but have the potential to be used outside school. Web-based learning **in** school was included in CAI. Definitions of blended and online learning (and synonyms) and Games, CSCL and CAI are offered. Previous literature relevant to this review is briefly surveyed, then Research Questions are given. Turning to Method, keywords, databases and inclusion/exclusion criteria are outlined. The coding framework is explicated and inter-rater reliability outlined. Results are then given, albeit in summary form. The paper ends with a Discussion (which discusses limitations and speculates beyond the research findings) and a Conclusion (which gives the answers to the Research Questions). Appendix A then lists pedagogical and design pointers drawn from the research evidence, while Appendix B offers briefer Teaching Points also drawn from the research evidence.

Introduction

Aims

During the corona-virus pandemic, many schools turned to online and blended learning in various forms to provide education for children who were not allowed in school. Papers have begun to appear on managing online and blended learning in a pandemic (e.g., Doucet, Netolicky, Timmers, & Tuscano, 2020), but these are typically just giving advice and listing resources with no evidential basis. We do not know how well schools have been delivering online or blended learning, and probably there has been great variation between schools (and possibly between teachers). Undoubtedly the transition from classroom work to online work has been extremely demanding for many teachers. Further, disadvantaged students may be less likely to have computers and internet connections at home (although they may be more able to access material delivered to mobile phones), and so the gap between advantaged and disadvantaged students seems likely to have increased. Indeed, Education Endowment Foundation (2020a) estimated the median effect of school closures so far to have widened the gap between advantaged and disadvantaged by 36% - a gap which could only be reduced by a multiplicity of measures.

The aim of this review is to explore the research literature on the effects of online or blended learning from schools to see whether it is better, worse or the same as traditional face-to-face classroom learning, in order that teachers might be better informed. If online or blended learning turns out to be as good as or similar to classroom learning, teachers may wish to extend their involvement in it even after children are able to return to school. Of course, there may be local lockdowns which require only a limited number of children to be in school, and blended learning would be ideal in that instance. The skills developed in delivering online

learning should not be lost by subsequent simple reversion to “what we always did before”. Thus, this project also aims to extract evidence-based teaching principles which teachers can put into practice. Of course, online learning may be good for some sub-groups of students but not others, and this needs to be made clear also.

Research studies are typically moderately well organised, so they may not be typical of what has recently happened in schools, which was a requirement to deliver support to pupils via online learning with little notice and time to prepare. Consequently, recent implementation might have been of uncertain quality in some schools and from some teachers, which might make recent practice less related to the research outcomes than would otherwise be the case. However, research studies are also affected by publication bias, in that authors are more likely to submit papers reporting positive results for publication, and journal editors are more likely to publish them. So, they may give a somewhat unrealistically positive picture of the effectiveness of intervention methods.

Given the need to get reliable information into the hands of teachers at the earliest possible date, we decided to produce this systematic review and make it immediately available to teachers via the Internet.

Definitions

Online Learning is a style of education in which students learn complete programmes of work only via electronic and online media, so that they can completely control the time, pace, and place of their learning (Oxford English Dictionary). In other words, all the learning happens out of school. However, many studies report what they call online learning when in fact they have the pupils in school using the school internet system to access some form of web-based programme under the supervision of the teacher. This is not what we consider to be online learning, and such projects have been categorised as Computer Assisted Instruction (CAI).

Blended Learning is a style of education in which students learn via electronic and online media as well as traditional face-to-face teaching in the classroom, so that they can, in part, control the time, pace, and place of their learning (Oxford English Dictionary). In other words, part of the learning happens out of schools and part of it happens in schools. Typically, information-giving happens out of school and interactive elements such as teacher and peer discussion happen in school. Typically, the in- and out-of-school aspects are closely synchronised, e.g., morning at home and afternoon in school. In both online and blended learning, online interactive sessions between teacher and student or between student and peers can be hosted through video conferencing, web chat, message boards or other means. In this review, online or blended learning may have taken place for an entire programme of learning, or it may only have taken place for the relatively brief project which is reported.

In this report we not only consider online and blended learning, but also computerised educational games and computer-supported collaborative learning, since these currently may be used mainly in school but clearly have the potential to be used in locations outside of school.

Computerised educational games are designed to help people learn about certain subjects, expand concepts, reinforce development, understand a historical event or culture, or assist them in learning a skill as they play, but do so within the context of a game which has rules and clear objectives (e.g., to “win”). They can be “serious” games designed especially for their educational value, or commercial games which nonetheless have educational value (and are often better produced). Games involve interactive play that teaches goals, rules, structure, adaptation and problem solving, all often represented as a story. They provide feedback and enable learning by giving enjoyment, passionate involvement, structure, motivation, ego gratification, adrenaline, creativity, social interaction and emotion. A “serious game” is a game designed to facilitate learning as well as entertainment (although adults would be well advised not to refer to them as “serious” games in front of the pupils). Games may be for single players, for two or several players, or be part of a massively arranged system for multiple cooperative teams or adversaries, as in Massive Multiplayer Online Games (MMOGs) (Wikipedia).

Computer Supported Collaborative Learning (CSCL) concerns how collaborative learning supported by technology can enhance peer interaction and enable work in groups, and how collaboration and technology facilitate sharing and distributing of knowledge and expertise among community members (Lipponen, 2002). The participants use the Internet and Internet-enabled software tools to support social and collaborative learning at a distance from one another and from their instructor. However, many CSCL projects have taken place within schools rather than outside them.

We did not include Computer Assisted Instruction (CAI) search terms in our literature search. However, as noted above, we found that many studies which purported to be of online or blended learning actually turned out to be school-based studies, where pupils had interacted with digital materials or used web-based materials in school while under the direct supervision of the teacher. Hence, we categorised these as CAI, a category which grew very large. Clearly, schools are using many forms of technology in schools which could be exported out of school, but this is not yet occurring to any considerable extent. Consequently, a definition of CAI is given: CAI is an interactive instructional technique using a combination of text, graphics, sound and video whereby a computer is used to present a programme of instructional material, have the student interact with it, and monitor the learning that takes place. CAI programmes can be simply drill and practice, or they can be much more complex, e.g., involving simulations (WikiEducator).

Many of the studies reviewed here compared digital technology to Traditional Instruction, so it is worth giving a definition of that also. Traditional classroom instruction is a structured program of face-to-face teacher-centred instruction, including the teacher giving information and teacher-led discussion. Instructional materials include textbooks, lectures and individual written assignments. All students in the classroom generally receive a single, unified curriculum. Particularly in secondary school, subjects are often individual and independent, whereas in primary school they may be integrated (Wikipedia).

Previous Literature

It is traditional in academic papers to commence with a lengthy review of the previous literature. However, in this case all the evidence-based literature since 2000 is encompassed in what follows, papers dated before 2000 will be out of date, and purely theoretical papers often show scant articulation with the empirical data. Consequently, this section is brief and to the point.

Many useful guides to blended learning appeared before the pandemic (e.g., Cleveland-Innes, & Wilton, 2017). Since the pandemic started, the Education Endowment Foundation (EEF) (2020b) has produced a rapid research review of online and blended learning from schools (https://educationendowmentfoundation.org.uk/public/files/Remote_Learning_Rapid_Evidence_Assessment.pdf). Although very valuable, this study only reviewed reviews and meta-analyses (and then not all of them), whereas we intended to review individual studies. The EEF also focused heavily on disadvantaged children, whereas we looked at other sub-groups. Further, the summary teaching points emerging from it were broad and rather difficult for teachers to operationalise. However, we used the reviews in the EEF and also all the single studies cited in those reviews since 2000 in our own review. This report also categorises these studies in the same way as the EEF report, i.e., as Online, Blended, Games, CSCL, or CAI.

In the US, Studies of Distance Learning (<https://ies.ed.gov/ncee/wwc/distancelearningstudy>) gives a list of studies relevant to online and blended learning across all sectors of education, which have partially stemmed from searching ERIC with regard to blended and online learning and partially from crowd-sourced suggestions for relevant studies. We extracted the studies concerned with schools and added them to our study.

Beyond this, Evidence for Learning Australia (<https://www.evidenceforlearning.org.au>) have been analysing single studies from the EEF Rapid Evidence Assessment. We also do this, but add findings from several other databases. The Scottish Government has also produced two papers on Blended Learning (<https://education.gov.scot/improvement/learning-resources/education-recovery-group-blended-learning>).

Research Questions

RQ1: Do online or blended learning from schools have positive/negative/similar effects compared to Traditional Instruction in school or another comparator?

RQ2: Do educational games and computer-supported collaborative learning have positive/negative/similar effects compared to Traditional Instruction in school or another comparator?

RQ3: Are the effects different between primary/elementary schools, middle schools and secondary/high schools?

RQ4: Are the effects different in different subjects?

RQ5: Are the effects different by gender?

RQ6: Are the effects different for different sub-groups of students, e.g., disadvantaged, “high” and “low” ability, those with special educational needs or disabilities, ethnic minorities, rural students, second language learners, the hospitalised and sick at home, gifted, and students in non-English-speaking educational contexts?

RQ7: Are the effects on socio-emotional functioning and psychological wellbeing positive/negative/similar compared to Traditional Instruction in school full-time?

RQ8: What is the evidence for design principles or underlying digital pedagogies in any of these studies?

RQ9: What teaching points can be drawn from evidence-based studies?

Method

Keywords

We used the following keywords in our search:

- school (including primary and elementary, middle, secondary and high) AND
- blended learning OR online learning OR e-learning OR elearning OR virtual learning OR distance learning OR remote learning OR digital teaching OR flipped learning OR flipped classroom OR computer supported collaborative learning OR computer supported cooperative work OR online cooperative work OR online collaborative learning OR educational games online OR educational video game OR serious games

We initially added a third term (AND effect OR impact OR outcome), but found that this seriously restricted the number of hits in different databases as these words did not appear frequently in titles, abstracts or keywords.

The whole search term was thus:

school AND “online learning” OR e-learning OR elearning OR “virtual learning” OR “distance learning” OR “remote learning” OR “digital teaching” OR “blended learning” OR “flipped learning” OR “flipped classroom” OR “Computer Supported Collaborative Learning” OR “Computer Supported Cooperative Work” OR “Online Cooperative Work” OR “Online Collaborative Learning” OR “Educational Games Online” OR “Educational Video Games” OR “Serious Games”.

When we came to Google Scholar, we found that inserting the whole search term was not efficient – it appeared to confuse its algorithms. By experimentation we found that inserting the type of school first (primary/elementary/middle/secondary/high) and then the type of intervention separately (“online learning” OR e-learning OR elearning OR “virtual learning” OR “distance learning” OR “remote learning” OR “digital teaching” / “blended learning” OR “flipped learning” OR “flipped classroom” / “Computer Supported Collaborative Learning” OR “Computer Supported Cooperative Work” OR “Online Cooperative Work” OR “Online Collaborative Learning” / “Educational Games Online” OR “Educational Video Games” OR “Serious Games”) yielded a far larger and more focused set of hits.

Databases

We searched the following research databases:

- ERIC
- JSTOR

- Scopus
- Web of Knowledge
- Google Scholar
- EEF Rapid Evidence Assessment: Reviews
- EEF Rapid Evidence Assessment Single Studies
- Studies of Distance Learning

All papers dated before 2000 were removed. Then, all papers which appeared from their title or abstract to be about learning other than in school education were removed. Papers not in English were removed. Papers which did not include data or evidence (whether quantitative or qualitative) were removed. Duplicates were removed. All whole books and chapters which did not have an abstract were removed and all other items without an abstract were removed. See the Prisma chart (Figure 1 below) for an indication of the quantity of papers from different databases – there were very different numbers from different databases. Also, the number of duplications were relatively small, indicating each database was effectively accessing a largely different range of items. While the EEF Rapid Review listed a considerable number of reviews, systematic analyses and meta-analyses of Online and Blended Learning, Games, CSCL and CAI, we found many more. Abstracts which appeared at first sight from the title or abstract to be relevant to the search were identified – 1540 of them. The full paper was obtained for each of these items and 185 were found not to conform to our selection criteria and so were excluded, leaving 1355 papers.

The Coding Framework

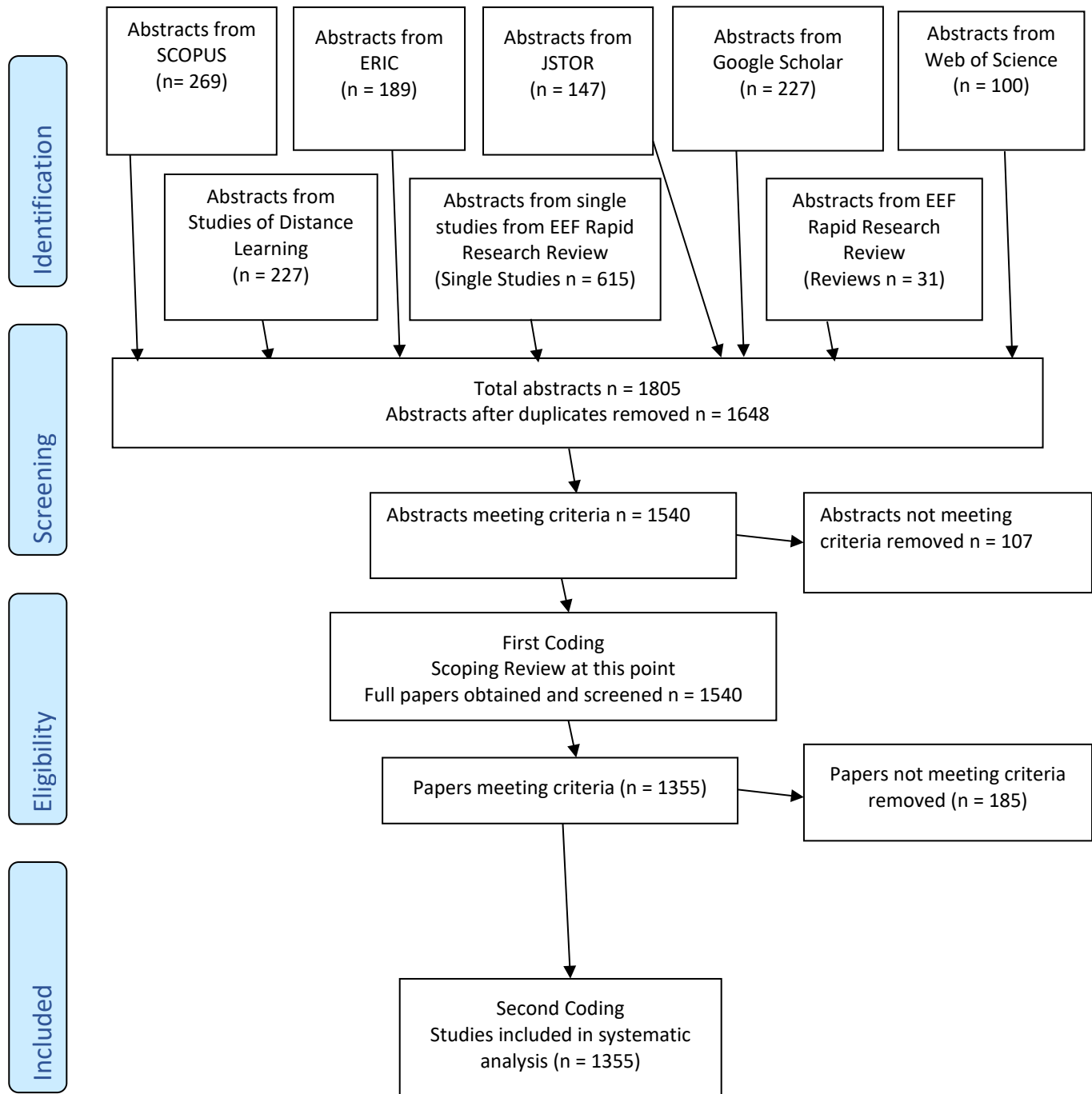
The 1355 full papers were then coded according to the research questions on which they provided data. Papers which were reviews or meta-analyses were coded as such. Papers were then coded according to whether they appeared to be in the Online, Blended, Games, CSCL or CAI categories (irrespective of what they claimed to be) (and studies which overlapped areas were multiply coded). Studies were then coded according to what sector of education they related to: Early Years or Kindergarten, Primary or Elementary, Middle, Secondary or high, Primary and Secondary together, and unclear (and again studies which overlapped areas were multiply coded). Early Years or Kindergarten was included as a category as many readers would not expect online or blended learning to be applicable to such young children.

Studies were then coded according to subject area: Reading, English, Writing, Math, Science, STEM (Science, Technology, Engineering and Mathematics), Thinking, English as a Foreign Language (EFL), Humanities (including history, geography, social studies, economics), Health (including physical education, nutrition, exercise, aggressive behaviour), and ArtsMusic (including composing, sculpting). These aggregate categories evolved from early attempts at coding and while encompassing considerable diversity, represented manageable categories.

Studies were then coded according to gender if that was mentioned, in relation to whether Females were better, Males were better, or Females and Males were equal. Studies were then coded according to sub-group: Socio-economically Disadvantaged, of High or Low ability (which turned out to be almost all of low ability), whether participants had any Special Educational Needs or Disability (and the type of that Disability), were of any Ethnic Minority within one country, were mainly in a Rural setting (since online and blended learning are



Figure 1
PRISMA 2009 Flow Diagram



particularly relevant for those far from a school), were Second Language Learners (although most of the findings were related to those studying English as a Foreign Language), Hospitalised or Sick at Home children, Gifted children, and those in a Non-English-Speaking Educational Context (since we wished to see how many different countries apart from English-speaking countries participants came from, in order to consider whether their host educational culture had any differences from Western Anglophone culture).

Then Outcomes were considered: was the intervention better, worse or the same compared to whatever it was being compared to? In many cases the comparison was to traditional teacher-led instruction (business as usual), but sometimes it was in comparison to another computer-led intervention. The comparator group might have been referred to as a control or comparison or alternative treatment group, but often was not. Some studies used a baseline design to compare student functioning with the functioning of the same students in a previous period. We did not include any indicator of the **degree** to which a study was Better/Worse, as many studies were qualitative and this was impossible to quantify. Where a study reported more than one outcome where the outcomes contradicted each other, both outcomes were coded (this accounts for some findings appearing to have more codings than the number of papers).

Then Socio-Emotional Functioning was considered – was there evidence that the implementation of online or blended learning had improved social functioning, worsened it, or had it stayed the same? Obviously, online learning in particular removes the face-to-face social interactions which pupils enjoy in school, so this category was apposite. Similarly, Psychological Well-being was considered, although relatively few studies mentioned this. Finally, coding considered whether the paper had implications for intervention design or described any underlying digital pedagogies. These were assembled as design points for information in Appendix A. Briefer teaching points were also extracted for Appendix B, but these were not coded.

Coding Definitions

Many studies which appeared to be of Online and Blended Learning did not in fact conform to our definition of these, which required children to be studying in part or wholly at home or otherwise outside of school, using the Internet and/or other digital technology. Such studies might well have had pupils using web-based learning or digital packages, but these tended to be studied only in school (using the school's own internet system), rather than in any way at home. Such studies were coded CAI rather than Online or Blended. We initially deliberately excluded Computer Aided Instruction (CAI) from our search terms as such methods are mostly only found in the classroom. However, many CAI methods have **potential** for use in blended learning, and where our search nonetheless discovered such items (which became very numerous), we have included them in our results here. Likewise, some of the Games and CSCL we reported were used in a classroom environment, but clearly had potential to be used in a blended learning environment. Only items which were clearly about Online Learning were coded under online learning, and only items clearly about Blended Learning were coded under blended learning.

One option we did not pursue was to code online/blended learning as either synchronous or asynchronous. It has been argued that web-based learning in school is more likely to be synchronous, whereas online/blended learning outside of school is more likely to be asynchronous, offering a higher level of flexibility concerning mode, place, pace and path. In the event, few of the abstracts mentioned this variable, most research finds no difference, and some studies use both synchronous and asynchronous, and so it was excluded.

Additionally, there was discussion of the concept of Non-English-Speaking Educational Context (NESEC), indicating countries where English was not the native language and where the educational context might be very different from what would be expected in the UK. Ethnic Minority (EM) would be used for an ethnic minority within a country, rather than between countries.

Full Papers and Inter-Rater Reliability

The 1540 full papers were divided between two senior researchers very familiar with this research area, who each read their portion. As a result, a further 185 papers were found not to meet the inclusion criteria, leaving 1355 to be coded for the full systematic review. Many of those excluded contained no outcome data related to student outcomes (n=90), some included no data from schools, many being located only in higher education (n=64), a few were beyond the scope of the study (for example, the case of a study of online learning to heighten participants' visual acuity, rather than any more ordinary educational achievement) (n=14), some were so obscure as to prove unobtainable despite our best efforts (n=12) and in three cases the full paper was in a language other than English (although an abstract was given in English). Inter-rater reliability of coding was assessed for a random sample of 100 items. The percentage of agreement between the coders was 95.6%. This high percentage was attributed to very clear and precise definition of the coding variables. We noted that of the 185 papers excluded, largely on the grounds that they gave no data on student outcomes, 17 of them nonetheless felt able to give recommendations regarding how to proceed.

Quality of Studies

We considered rating Quality of Evidence from 1 to 4 using the GRADE framework of Guyatt, Oxman, Akl, Kunz, Vist, Brozek, et al. (2011), but the studies were so various and quite often key aspects of research design were omitted, so that obtaining a satisfactory level of inter-rater reliability proved impossible. Consequently, this was eventually considered too subjective and unreliable for weighting purposes.

Results

Analysis by Intervention and Outcome

Analysis of data by intervention and outcomes is shown in Table 1. As noted earlier, 1355 studies were included in this systematic review. Dividing the interventions mentioned in the papers into area of operation, we found: Online 134 studies (7%), Blended 232 (13%), CSCL 129 (7%), Games 488 (26%), and CAI 865 (47%) (some studies encompassed more than one

area of operation). Clearly, Games and CAI were categories containing many studies, while Online and CSCL contained least, with Blended Learning somewhere in the middle.

Considering the overall totals regarding outcomes, the general picture was very positive - 1576 mentions in studies found digital technology better than Traditional Instruction (85%), while 146 (8%) found it the same and only 46 (3%) found it worse (see Table 1). This is clearly a major finding, indicating that digital technology is almost always superior to Traditional Instruction, although of course publication bias has to be taken into account.

Among the interventions, CAI clearly appears as the most effective in terms of number of papers reporting it Better than Traditional Instruction (91%) (but we have to be aware that if CAI were implemented more out of schools than in, a lower figure may ensue). Next comes Blended Learning (83%), not far ahead of Games and CSCL (both 81%) (although again we must remember that Blended Learning takes place partly out of school while the other interventions might not). A fair way behind comes Online Learning (74%), although we must remember that this also represents a good degree of effectiveness, even if Online Learning has more Same and Worse results than other interventions.

Comparing Online with Blended Learning, Blended Learning clearly did better, both in terms of being better but also when adding better and same results together (which is relevant for these alternatives to Traditional Instruction). Regarding CAI, Games and CSCL, which tend to be used in schools but less so outside of schools, the Better figure is the most important, since no teacher would be interested in using a method in school which only gave the same results as existing methods. Here CAI is clearly the best, with Games and CSCL coming equal second. However, it should be noted that some studies coded as CSCL did not set out to measure learning improvement, but instead some variant of Socio-Emotional Functioning (SEF) such as communication, social interaction or self-efficacy. It should be also noted that Blended Learning gives better results than either of these latter two.

Table 1
Summary Data for Interventions

Intervention	Better	Same	Worse	Unclear
Online (n=134, 7%)	99 (74%)	17 (13%)	11 (8%)	7 (5%)
Blended (n=232, 13%)	192 (83%)	21 (9%)	6 (3%)	13 (5%)
CSCL (n=129, 7%)	104 (81%)	9 (7%)	3 (2%)	13 (10%)
Games (n=488, 26%)	397 (81%)	44 (9%)	14 (3%)	33 (7%)
CAI (n=865, 47%)	784 (91%)	55 (6%)	12 (1.5%)	14 (1.5%)
Overall Total (n=1848, 100%)	1576 (85%)	146 (8%)	46 (3%)	80 (5%)

Some papers were coded for more than one intervention. Figures represent mentions, not papers.

Reviews and Meta-analyses

We also noted among the 1355 papers a very large number of reviews and meta-analyses which included schools in their purview – 144 in total, divided into Online 19, Blended 20, Games 56, CSCL 14 and CAI 35 (see Table 2). Unfortunately for our purpose, many of these reviews (81%) covered primary, secondary and higher education (and even beyond) together and made no attempt to distinguish between them. Where this was the case, the majority of the studies usually came from higher education. It was rare for there to be any discrimination in the findings about what sector of education studies came from. Additionally, we noted that the number of reviews of Online Learning and Games proportionately far exceeded the number of papers in those categories, while the number of reviews of CAI was well below what might have been expected from the number of papers. Blended Learning and CSCL were more or less proportionate.

Table 2
Summary Data for Reviews and Meta-analyses

Intervention	Better	Same	Worse	Unclear
Online (n=19, 13%)	13 (68%)	5 (26)	0	1 (5%)
Blended (n=20, 14%)	19 (95%)	1 (5%)	0	0
CSCL (n=14, 10%)	13 (93%)	0	0	1 (7%)
Games (n=56, 39%)	49 (88%)	2 (4%)	0	5 (8%)
CAI (n=35, 24%)	29 (83%)	3 (8.5)	0	3 (8.5%)
Overall Total (n=144, 100%)	129 (90%)	11 (5%)	0	10 (5%)

Some papers were coded for more than one school sector. Figures represent mentions, not papers.

In Online Learning we found that of the 19 reviews, 13 of them found Online Learning better than Traditional Instruction (72%), while five found it equivalent and one paper was unclear. Only seven of these reviews gave Effect Sizes, and these ranged from -0.03 to 0.38, with a mean of 0.16. None focused on a specific sector of education. (Effect Sizes – ESs – are a quantitative measure of the magnitude of an effect. The larger the Effect Size the stronger the relationship between two variables. Positive ESs range from 0 to 1, and sometimes above that if the positive effect is very strong. Negative ESs indicate a negative or worsening effect. By contrast, statistical significance varies with the size of the sample.)

In Blended Learning we found that of the 20 reviews, all of them found Blended Learning better than Traditional Instruction except one (95%), which found it equivalent. Only six of these reviews gave Effect Sizes, and these ranged from 0.20 to 0.98, with a mean of 0.48. Only two focused on a specific sector of education.

In Games we found that of the 56 reviews, all of them found Games better than Traditional Instruction (88%), except two which found it equivalent and five which were unclear. Only 11 of these reviews gave Effect Sizes, and these ranged from 0.13 to 1.13, with a mean of 0.48. Only six focused on a specific sector of education.

In CSCL we found that of the 14 reviews, all of them (93%) found CSCL better than Traditional Instruction except one, which was unclear. Only seven of these reviews gave Effect Sizes, and these ranged from 0.20 to 0.95, with a mean of 0.49. Only two focused on a specific sector of education.

In CAI we found that of the 35 reviews, all of them found CAI better than Traditional Instruction (83%), except three which found it equivalent and three which were unclear. Only 11 of these reviews gave Effect Sizes, and these ranged from 0.13 to 2.5, with a mean of 0.81. Only six focused on a specific sector of education.

From the mean Effect Sizes at first sight, it might appear that CAI is the most effective intervention, while Blended Learning, Games and CSCL are of moderate but somewhat less effectiveness, followed by Online Learning which seems the least effective (although still somewhat effective). However, we urge extreme caution in interpreting these figures, not least because Online and Blended Learning take place out of school, while the other three take place in school. Further caution is demanded by the fact that relatively few of these reviews focused solely on a sector clearly of school age, and consequently disparate locations and contexts are muddled together. In any event, the Effect Sizes for each intervention are extremely heterogeneous. A more reliable picture is likely to be obtained by looking at the individual papers overall. Nonetheless, these results are not dissimilar to those for all papers separately (above), except that when considering the individual papers Blended Learning seems to do rather better than in the reviews.

Analysis by Subject and Sector

Analysis by subject and sector is shown in Table 3. It was clearly of interest to investigate the extent to which these overall positive findings remained when different sectors of education were analysed: Early Years Kindergarten, Primary, Middle, Secondary and Primary + High schools. We created a matrix which explored the interactions between these factors. Within this matrix (in each cell) we also investigated subjects: Reading, Maths, Science, STEM, Thinking, EFL, Humanities, English, Health, Art Music, and Writing. Within each sub-cell, we also investigated Outcomes: Better than Traditional Instruction, Same, Worse or Unclear. The resulting matrix was extremely complex and here we merely try to summarise it.

Looking at summary data for school sectors in Table 3, the general picture is again very positive - 82% of these interventions did better than Traditional Instruction, while 10% were the same and only 3% were worse. It is clear that the Primary/Elementary sector and the Early Years/Kindergarten sector showed the highest rate of success (both 87%), and this is particularly startling for those who did not expect digital technology to be widely used with young children in Kindergarten settings. Secondary/High comes next with 80%. Primary/Secondary comes next, below both Primary and Secondary separately, perhaps raising questions about the wisdom of trying to include participants from both sectors

simultaneously in such research/practice. Curiously, last of all comes Middle Schools with 73%. It is difficult to see why Middle Schools should do least well, although they did have more outcomes the Same as Traditional Instruction.

Turning to subjects, Science (21% of the total) and Maths (20%) were the most popular subjects, followed by Thinking (10%), Reading (9%), English as a Foreign Language (EFL) (7%), Humanities (5%), Health (5%), STEM (4%), Writing (4%), English (2%), Arts/Music (1%) and Foreign Language (1%). Some papers (mainly reviews and meta-analyses but also reports covering a large geographical area) covered All Subjects (n=166, 11%). In terms of effectiveness, all areas were above 80% for Better status except English (77%), but there were some small differences between subjects: EFL interventions were the most effective (90%), followed by Writing and STEM (89%), then Thinking (88%), Arts/Music (87%), Humanities (86%), Health and Science (84%), Reading and Math (82%), Foreign Languages (81%) and English (77%). Thus, the most popular subjects were by no means those where the greatest effectiveness was evident, although the differences are small and only the largest differences are likely to be significant.

Other more nuanced findings are evident from the whole matrix. Games and CAI obviously dominate in terms of number of studies, particularly at Primary level, with Games much more prevalent at Primary than Secondary. Maths and Science are the most common subject for Games and CAI in Primary, joined by Reading especially in CAI. However, Games are also common for many other subjects in Primary and similarly (although to a lesser extent) in Secondary. However, in Secondary, Maths becomes less common and Science becomes more common in CAI, while Reading disappears from Games.

Table 3
Summary Data for School Sectors

School Sector	Better	Same	Worse	Unclear
Early Years/ Kindergarten (n=45, 3%)	39 (87%)	2 (4%)	1 (2%)	3 (7%)
Primary/ Elementary (n=536, 39%)	468 (87%)	47 (9%)	8 (1.5%)	13 (2.5%)
Middle (n=127, 9%)	93 (73%)	20 (16%)	6 (5%)	8 (6%)
Secondary/ High (n=460, 33%)	370 (80%)	55 (12%)	18 (4%)	17 (4%)
Primary + Secondary (n=214, 16%)	165 (77%)	20 (9%)	8 (4%)	21 (10%)
Overall Total (n=1382, 100%)	1135 (82%)	144 (10%)	41 (3%)	62 (5%)

Some papers were coded for more than one school sector. Figures represent mentions, not papers.

Blended Learning seems more frequent at Secondary than Primary. Reading largely disappears at Secondary level. Science seems to be the most popular subject, with Maths following shortly behind. However, a wide range of subjects are studied at both Secondary and Primary. Health subjects seem to do particularly well. Online seems to focus more on Maths at Primary level and more on Science at Secondary level, although Reading is present at both levels. English as a Foreign Language is also widely pursued through Online Learning (and features in Blended Learning as well). CSCL is somewhat similar, with less emphasis on Reading and Maths at Secondary and more on Science.

Other Moderator Variables

Many other moderator variables were present in such modest numbers that generally it was not felt helpful to further subdivide them into each of the five intervention categories. Consequently, effects are generally indicated for all digital interventions together.

Gender was coded according to whether Females did better, Males did better, or whether Males and Females were equal. Females were better in 27 cases (39%) and Males better in only 6 (9%). Males and Females were equal in 36 cases (52%). Thus, somewhat contrary to expectations, overall girls did better than boys at digital learning in many studies, although many studies had girls and boys doing equally well.

Special sub-groups were coded according to whether they were: Disadvantaged, of HiLo Ability (almost all of “low ability”), had Special Educational Needs or Disabilities, were from an Ethnic Minority, were from Rural areas (where remote learning might be more needed), were Second Language Learners (almost all EFL studies), were Hospitalised or Sick at Home children, were Gifted, and whether they came from a Non-English-Speaking Educational Context. Studies coded as Disadvantaged numbered 46 (3%), HiLo 82 (6%), a variety of Disability 112(8%), Ethnic Minority status 30 (2%), Rural 34 (3%), Second Language Learners 76 (6%), Hospitalised or Sick at Home 7 (1%), Gifted 10 (1%) and Non-English-Speaking Educational Context 329 (24%).

The Disadvantaged subgroup numbered 46, and in many cases such children performed better than Traditional Instruction (n=37, 79%), with only six Same and two Worse codings. This is a slightly worse outcome than for all students combined (85%), but nonetheless suggests that Disadvantaged children can make almost as large gains as other children, when usually they would be expected to perform much more poorly. Nonetheless, it also indicates that Online or Blended Learning hinders disadvantaged students still further, and widens the gap between the advantaged and the disadvantaged. Regarding the Disadvantaged group, we expected to encounter some direct discussion of the presumed difficulties for socio-economically disadvantaged children of accessing computer and the Internet at home, but there was very little of this, other than some comment on such children possibly having less support from parents, who would need to work and in the case of blended or online learning would be leaving the child at home unaccompanied, which of course would be illegal in the case of young children. Further, given the attainment gap between advantaged and disadvantaged students, there appeared a danger that Online or Blended Learning would serve only to make that gap wider. Generally, the mention of Disadvantaged was in the context of investigating whether digital technology worked with such children, which it usually did once it was made

reliably available. Some schools had made iPads or laptop computers available to Disadvantaged children to take home, with positive results. A few studies had tried using mobile phones rather than computers and the Internet. There was also comment on the loss of educational capability during the summer break for disadvantaged children.

The code HiLo almost exclusively related to “low ability” children (as they might be perceived by the teacher) (n=82), and in the vast majority of cases HiLo children performed better than Traditional Instruction (n=76, 92%), with only three Same and two Worse codings. This is a better outcome than for all students combined (85%). This suggests that children operating in the digital space can prove surprisingly competent when given the opportunity (although “weaker” students might be expected to perform more poorly), and low ability students are not disadvantaged by Online or Blended Learning. However, direct comparisons of low ability and average ability students was rare. An early start with Kindergarten children was found effective.

The Special Educational Need or Disability code (n=112) revealed use of digital technology in a number of studies of children with very various needs (see Table 4), including: All unspecified SEN 24 (21%), Learning Difficulties 30 (27%), Autistic Spectrum Disorder 14 (13%), Attention Deficit and Hyperactivity Disorder 10 (9%), Visual Impairment 5 (4%), Emotional and Behavioural Disorder 6 (5%), Deaf and Hard of Hearing 5 (4%), Dyslexia/Specific Learning Difficulties 5 (4%), Down Syndrome 3 (3%) and Writing Difficulty 3 (3%). Overall, 89 studies (80%) found Better outcomes, which is not much lower than the average for all students. However, this still means that the gap between Special Needs students and the rest of the student population is continuing to widen. Nonetheless, this aggregate figure is worth disentangling into types of disability, which give more complex results.

On the positive side, Deaf and Hard of Hearing, Down Syndrome and Writing Difficulty students had 100% Better ratings, albeit with very modest numbers of studies (3-5). Attention Deficit and Hyperactivity Disorder (ADHD) students had a 90% Better rating (out of 14 studies), followed closely by Learning Difficulty (87% of 30 papers - the highest number of papers) and Autistic Spectrum Disorder (ASD) (86%; 14 studies) students. All of these were above the average for all students. On the less positive side, Unspecified Disabilities (out of 24 studies) and Emotional and Behavioural Difficulties (out of six studies) both only had a 67% Better rating. Visual Impairment was 60% (five studies, although three were Better and two were Unclear). Dyslexia/Specific Learning Difficulty was least effective (50%) with two Betters, one Same and one Unclear. However, it should be noted that of these 112 studies, only one had a Worse outcome (1%).

Ethnic Minority Status (n=30) was often seen in US studies as Afro-American (7 studies) or Hispanic (8 studies). However, East Africans also featured (2 studies) as did Native Americans and Maori (1 study each). Ten studies spoke of all ethnicities without specifying. With Ethnic Minorities, 25 (78%) of studies reported Better performance, five (16%) Same and two (6%) Worse. This was similar to the performance of Disadvantaged students, indicating that EM children can make almost as large gains as other children, when usually at least some Ethnic Minorities might be expected to perform more poorly. Nonetheless, the gap between Ethnic Minority and other pupils continues to widen. More than one study commented that Computer Science was dominated by White and Asian males.

Table 4

Summary Data for Special Educational Need or Disability Sectors

Impact Rank	SEN/Disability	Better	Same	Worse	Unclear
7=	Unspecified (n=24, 21%)	16 (67%)	3 (12.5%)	1 (4%)	4 (16.5%)
5	Learning Difficulty (n=30, 27%)	26 (87%)	3 (10%)	0	1 (3%)
6	Autistic Spectrum Disorder (n=14, 13%)	12 (86%)	1 (7%)	0	1 (7%)
4	ADHD (n=10, 9%)	9 (90%)	0	0	1 (10%)
9	Visual Impairment (n=5, 4%)	3 (60%)	0	0	2 (40%)
7=	EBD (n=6, 5%)	4 (67%)	2 (33%)	0	0
1=	Deaf & HoH (n=5, 4%)	5 (100%)	0	0	0
10	Dyslexia/SLD (n=4, 4%)	2 (50%)	1 (25%)	0	1 (25%)
1=	Down Syndrome (n=3, 3%)	3 (100%)	0	0	0
1=	Writing Difficulty (n=3, 3%)	3 (100%)	0	0	0
	Miscellaneous (n=8, 7%)	6 (75%)	1 (12.5%)		1 (12.5%)
	Overall Total (n=112, 100%)	89 (80%)	11 (9.5%)	1 (1%)	11 (19.5%)

Some papers were coded for more than one school sector. Figures represent mentions, not papers.

Rural schools (n=34) were widely seen as problematic, not just because of a lack of hardware and Internet connectivity, but also because in some countries Rural school income could be less and the teachers could be less qualified. However, 29 studies (85%) found that innovations were better than Traditional Instruction effective in rural schools, while two were the Same (6%) and two were Worse (6%). This was similar to the performance of all students taken together (85%), so there was no evidence that Rural schools were under-performing. Schemes like My Buddy School linking a rural and an urban school and the wider use of mobile phones were interesting. One study distributed iPads while another distributed the much cheaper Raspberry Pi. A third distributed unspecified tablets with Games on them. Online mentors were also mentioned.

We hoped the coding for Second Language Learners (n=76) would help us discover students who were not speaking their native language in class. However, the bulk of this category was taken up by English as a Foreign Language learners. Nonetheless, the mostly EFL students showed high levels of performance: 69 (90%) proved Better than Traditional Instruction, while 7 (9%) were the Same and only one (1%) Worse. Thus, these mostly EFL students were performing at a higher level than was average for all students.

A few studies (n=7) focused on children who were Hospitalised or Sick at Home, which was acknowledged to be a very difficult situation. Some studies focused on children with chronic conditions (e.g., leukaemia) who were hospitalised for a long time, while other studies considered conditions which did not require long-term hospitalisation. Six of these (86%) found the children were Better after the intervention, and only one was the Same (14%). Thus, despite the difficulties, the performance was virtually the same as that for all children taken together.

The Gifted coding (n=10) showed eight studies Better (80%) and two the Same (20%). Thus, the performance for Gifted was a little below the average for all students, but the numbers are small so that not too much significance should be attached to this finding. There were studies concerned with intervention with gifted students in mathematics (two studies), language, writing, neuroscience and metacognition. Two studies compared gifted and non-gifted students and expressed surprise when the non-gifted did as well as the gifted. This perhaps suggests that “giftedness” is traditionally defined by the school and pupils with digital competencies may achieve unexpected performance in that area. Gifted students found virtual learning little different from traditional learning at school, apart from the social side of life.

Non-English-Speaking Educational Context (NESEC) was coded whenever the title or abstract indicated the study had taken place in a country which did not have English as its first language (although the study was of course written in the English language). This was intended to show whether different cultural factors might be operating which could influence the success or otherwise of the digital technology. The following countries were so identified (in order of frequency of studies and then alphabetically): Taiwan 67, Indonesia 32, Turkey 29, China 19, Hong Kong 14, Spain 13, Malaysia 12, India 11, South Korea 10, Iran 9, Netherlands 8, Thailand 8, Greece 5, Singapore 5, Chile 5, Israel 4, Mexico 4, Brazil 4, Cyprus 3, Czech Republic 3, Nigeria 3, Columbia 3, France 3, Italy 3, Philippines 3, Saudi Arabia 3, Sweden 3, Denmark 2, Ethiopia 2, Finland 2, Germany 2, Japan 2, Kenya 2, Kuwait 2, Norway 2, Oman 2, Poland 2, Sudan 2, Austria 1, Belgium 1, Costa Rica 1, Ecuador 1, Ghana 1, Hungary 1, Iraq 1, Jordan 1, Malawi 1, Morocco 1, Nepal 1, Palestine 1, Peru 1, Portugal 1, Slovakia 1, Slovenia 1, South Africa 1, Sri Lanka 1, Switzerland 1, Ukraine 1, United Arab Emirates 1 (59 countries, 329 papers, 24% of the total number). Clearly, interest in this area occurs all over the world. It seems very likely that there are cultural features that need taking into account when implementing any digital technology. The size and population of a country (and to an extent its level of economic development) seems to bear no relationship to its productivity in this area. Interestingly, when we examined the effectiveness of the studies which had taken place in a country which did not have English as its first language, we found that they had higher effectiveness than other studies (Better ratings 293 out of 329, 89%). Only four studies (1%) found Worse outcomes, while Same and Unclear were 5% each.

Table 5 reports changes in Socio-Emotional Functioning (SEF) as a result of engagement with digital technology. Overall, improvement was reported by 221 studies (87%), while only 9 (4%) reported a deterioration. A further small number (19, 7%) found no difference and six (2%) were unclear. However, a large number of these 221 positive studies were reporting an improvement in self-efficacy, rather than social functioning per se. When these figures are related to the ratings for other outcomes, we find that SEF+ has 207 Betters (90%), 15 Same, two Worse and four Unclear. However, SEF- has eight Betters (42%), three Same, seven Worse and one Unclear. SEF= had six Betters (75%), one Same and one Unclear. The difference in other outcomes between SEF+ and SEF- studies is striking, and suggests that Socio-Emotional Functioning, and in particular self-efficacy, makes an important contribution to effectiveness.

Table 5
Summary Data for Socio-Emotional Functioning (SEF)

SEF Factor	Better	Same	Worse	Unclear
SEF+ (n=228, 90%)	207 (90%)	15 (7%)	2 (1%)	4 (2%)
SEF= (n=8, 3%)	6 (75%)	1 (12.5%)	0	1 (12.5%)
SEF- (n=19, 7%)	8 (42%)	3 (16%)	7 (37%)	1 (5%)
Overall (n=255, 100%)	221 (87%)	19 (7%)	9 (4%)	6 (2%)

Some papers were coded for more than one school sector. Figures represent mentions, not papers.

Psychological Well-Being (PWB) was a rarely coded option, only 14 studies (79%) noting an improvement in this area. However, only two studies stayed the same (14%) and one study was coded as Unclear (7%). Relating these figures to the ratings for other outcomes in these studies, PWB+ has 11 Betters (79%), two Same and one Unclear. Thus, PWB does not seem to make as large a contribution to outcomes at SEF, although the numbers are so small that caution is needed in interpretation. Nonetheless, Psychological Well-Being seems likely to improve with digital technology, and is strongly associated with educational attainment.

A large number of studies were coded as having evidence-based implications for the Design of interventions or for the Digital Pedagogy which they entailed – 331 (24%). As these would be of interest to teachers, we broke them down by intervention. We had 367 pointers regarding design and pedagogy to consider: 40 concerning Online Learning (11%), 65 concerning Blended Learning (18%), 117 concerning Games (32%), 49 concerning CSCL (13%) and 96 concerning CAI (26%). These figures were very similar to the numbers in which these categories occurred, except CAI was substantially lower – perhaps surprising as CAI was such a various category. The Design and Pedagogy points for each intervention category are too extensive to list here, but readers will find these in Appendix A. Readers will find interesting similarities between some pointers in different intervention areas – and possibly some contradictions.

Discussion

Summary

This systematic review included 1355 studies, divided into: Online 134 studies (7%), Blended 232 (13%), Computer Supported Cooperative Learning (CSCL) 129 (7%), Games 488 (26%), and Computer Assisted Instruction (CAI) 865 (47%) (some studies were coded as of more than one type). Overall, digital technology was found more effective than Traditional Instruction in 85% of studies, while 8% found it the same and only 46 (3%) found it worse. Blended Learning was considerably more effective than Online Learning (83% of studies more effective than Traditional Instruction or other comparator conditions compared to 74%). Introducing other conditions which generally do not currently take place out of school, (CAI) was the most effective (91%), not far ahead of Games and (CSCL) (both 81%).

Reviews and meta-analyses numbered 144 in total: Online 19, Blended 20, Games 56, CSCL 14 and CAI 35. Unfortunately, 81% of these covered primary, secondary and higher education (and even beyond) together and made no attempt to distinguish between them. Nonetheless, Blended Learning had 95% of review studies Better than Traditional Instruction, CSCL 93%, Games 88%, CAI 83% and Online 72%. However, mean Effect Sizes (ESs) (such as were available) suggested CAI was the most effective, followed by Blended Learning, Games and CSCL, followed by Online Learning. While the latter was in keeping with the overall finding for all separate studies, great caution is needed in interpreting these figures.

Regarding school sector, Primary and Early Years/Kindergarten both had 87% Better than Traditional Instruction, while Secondary/High came next with 80%. Primary/Secondary came next, and last of all Middle Schools with 73%. This latter still suggests three quarters of studies were more effective than Traditional Instruction. Turning to subjects, Science and Maths were the most popular subjects (around 20% of the total each), then in order of popularity Thinking, Reading, English as a Foreign Language (EFL), Humanities, Health, STEM, Writing, English, Arts/Music and Foreign Languages (from 10% to 1%). EFL interventions were the most effective (90%), then Writing and STEM (89%), Thinking (88%), Arts/Music (87%), Humanities (86%), Health and Science (84%), Reading and Math (82%), Foreign Languages (81%) and English (77%). Thus, the most popular subjects were by no means those where the greatest effectiveness was evident, although the differences are small. Regarding gender, Females were Better in 27 cases (39%) and Males Better in only 6 (9%), but Males and Females were equal in 36 cases (52%). Thus, overall, females did better.

Studies coded as Disadvantaged numbered 46 (3%), HiLo 82 (6%), a variety of Disability 112(8%), Ethnic Minority status 30 (2%), Rural 34 (3%), Second Language Learners 76 (6%), Hospitalised or Sick at Home 7 (1%), Gifted 10 (1%) and Non-English-Speaking Educational Context 329 (24%). The Disadvantaged subgroup numbered 46, and in (n=37) 79% of these the children performed Better than Traditional Instruction. This is a slightly worse outcome than for all students combined (85%), but nonetheless suggests that Disadvantaged children can make almost as large gains as other children, when usually they would be expected to perform much more poorly. HiLo studies were mostly of low ability children, and in the vast majority of cases HiLo children performed Better than Traditional Instruction (n=76, 92%), suggesting the digital space allowed them to flourish.

Turning to studies including children with Special Educational Needs (SEN) or Disability, unspecified SEN were 18 (16%), Learning Difficulties 34 (30%), Autistic Spectrum Disorder (ASD) 14 (13%), Attention Deficit and Hyperactivity Disorder (ADHD) 10 (9%), Visual Impairment 7 (6%), Emotional and Behavioural Disorder (EBD) 6 (5%), Deaf and Hard of Hearing 5 (4%), Dyslexia/Specific Learning Difficulties 5 (4%), Down Syndrome 3 (3%) and Writing Difficulty 3 (3%), with other conditions less than 3%. Overall, 89 studies (80%) found Better outcomes, which is not much lower than the average for all students, but this aggregate figure can be disentangled into types of disability. On the positive side, Deaf and Hard of Hearing, Down Syndrome and Writing Difficulty students had 100% Better ratings, albeit with very modest numbers of studies (3-5). ADHD students had a 90% Better rating (10 studies), followed closely by Learning Difficulty (87%) (with the highest number of papers – 30) and ASD (86%; 14 studies) students. All of these were above the average for all students.

Regarding Ethnic Minorities, 25 (78%) of studies reported Better performance, five (16%) the Same and two (6%) Worse. This was similar to the performance of Disadvantaged students, indicating that EM children can make almost as large gains as other children, when usually they would be expected to perform more poorly. Regarding Rural schools, 29 (85%) found that digital technology was Better than Traditional Instruction. Thus, Rural schools appeared to perform as well as the average for all schools. The Second Language Learner (SLL) code mainly encompassed EFL learners. They showed high levels of performance, 69 (90%) Better than Traditional Instruction.

Regarding Hospitalised or Sick at Home studies, six of these (86%) found the children were Better after the intervention, and only one was the Same (14%). Thus, performance was virtually the same as for all studies taken together. Regarding Gifted studies (n=10), eight studies were Better (80%) and two the Same (20%). Thus, the performance for Gifted was a little below the average for all students. Regarding Non-English-Speaking Educational Context (NESEC) (the study had taken place in a country which did not have English as its first language), these studies had higher effectiveness than other studies (Better ratings for 293 out of 329, 89%).

Socio-Emotional Functioning (SEF) as a result of engagement with digital technology (mostly focused on self-efficacy) was reported by 225 studies, and 91% (207) of these were Better than Traditional Instruction. Regarding Psychological Well-Being (PWB) 14 studies out of 17 (79%) noted an improvement. Thus, PWB does not seem to make as large a contribution to outcomes at SEF, although the numbers are so small that caution is needed in interpretation.

A large number of studies were noted as having implications for the Design of interventions or for the Digital Pedagogy which they entailed – 331 (24%). We broke them down by intervention and readers will find them in Appendix A. We also extracted briefer Teaching Points and readers will find these in Appendix B.

Limitations and Strengths

We think that the broad terms of the search and the variety of databases used are positive features of this study. As the PRISMA chart shows, different databases tended to yield very

different studies, and so we have a wide range of studies. However, the issue of publication bias must be considered. Authors tend to submit and editors tend to publish papers that report positive results, so the published papers here might not be a representative sample of all research that was done. However, we have included doctoral theses, which were not peer reviewed or published in the normal way and more often gave weaker or negative results. We have however excluded books, chapters without an abstract and any forms of “grey” literature, which may have restricted the range of the study, but it still includes a very large number of studies.

We did not search for any studies dated prior to 2000, although we accept that there are examples of interesting and substantial work which were published before that. We felt that such older work would mostly have been overtaken by more recent findings. Readers will have noted that we did not insert any search terms specifically designed to extricate CAI interventions, but nonetheless CAI was the largest category of interventions. There were however keywords in the search which might have served to facilitate this extraction, such as “e-learning OR elearning OR virtual learning OR digital teaching”, which lend themselves to finding CAI interventions used in schools. Additionally, Subjects were grouped to conform to a relatively small number of categories, which sometimes included great variety, although this was done on the grounds of manageability. For example, the Humanities category included: Social Studies, History, Geography, Economics, Politics and so forth, which might have merited closer inspection.

We accept that the categorisation of studies into those which yielded a Better, Same, Worse or Unclear effect than Traditional Instruction (or other comparison group) is rather crude. Some readers of a positivist persuasion might wish for some indication of the degree to which interventions were “Better” or “Worse”, supported by tests of statistical significance, but statistical significance is a function of sample size and some papers were purely qualitative. Additionally, studies containing multiple contradictory findings were multiply coded, and the Inter-rater Reliability was very high, so at least there was consistency between coders. Similarly, some of the other codes could be open to various interpretation, but these were carefully and specifically defined and again Inter-rater Reliability was very high.

We intended to investigate the correlation between study sample size and mean Effect Size (ES) where available, to see whether small studies were more likely to produce small ESs, i.e., that publication bias was not militating against small studies. However, of the Effect Sizes available, 81% came from studies involving higher education students as well as school students, and it proved impossible to conduct this analysis. For the same reason, we could not employ measures such as Orwin’s (1983) failsafe N to investigate how many missing studies would be needed to bring the ESs to the $p=0.05$ level.

There is also a question of interpretation of results here. For Online and Blended Learning which are intended as substitutes for traditional classroom instruction, a “Same” outcome is positive (although not as positive as a “Better” outcome). However, this is not true of Games, CAI or CSCL, which are usually an addition to the normal classroom curriculum. In these cases, “Same” would mean the outcome was just the same as normal classroom instruction but the teacher would have incurred expense in purchasing the technology and time in learning how to use and manage it (although this would also be true of any other digital innovation).

Interpretation

One might assume that online and blended learning would have adverse social effects, since separating children from their friends as well as opportunities for direct cognitive interaction with the teacher and other students seems intuitively likely to be damaging. However, this was not posed as a research question in many studies. Nonetheless, we found that those studies which addressed Social and Emotional Learning tended to report a positive effect, but of course many studies did not explore this issue.

Worryingly, some studies of purely virtual schools in the USA (schools teaching only online which children can opt to “attend” rather than traditional schools) have reported that achievement in such schools was below that in traditional schools (Miron, et al., 2016; Ahn et al., 2017; Miron, et al., 2018; Poelmans, et al., 2018; Mislevy, et al., 2020). This could be related to the fact that disadvantaged Caucasian students were over-represented in such schools.

While we have found that online and blended learning are effective, and often more effective than Traditional Instruction, both of them beg the question of degree of parental or other carer supervision at home. In countries where extended families are not common, and especially in a situation where both parents need to work and therefore be absent from the house, the child-minding function of school becomes much more significant. Obviously with young children there are also legal issues to consider, but even with older children the question of how on-task they would remain when in the house on their own is another issue. When the online or blended work done at home is assessed quite quickly, the school can see which students are failing to keep on task (or procrastinating), and can perhaps require that they attend school in order to complete their online or blended tasks in an environment where there is a degree of supervision. This might be particularly relevant for disadvantaged pupils who might also have difficult accessing computers and the internet at home. Once the student is performing more satisfactorily, they might be allowed to resume studies at home. Thus, the student can see that working at home is a privilege that can be withdrawn if performance does not keep up to standard.

Ideally, online and blended learning should be available on a variety of devices to improve access, including smart phones and games consoles as well as desktop/laptop computers and tablets requiring an internet connection. One of the advantages of games is that they often do not require an internet connection. However, multiple device platforms should be considered, as for example a spreadsheet task presents particular problems when viewed on a smartphone.

While we had anticipated a high number of studies in CAI, we were surprised by the very large number of studies on Games. This is clearly an area of great productivity. However, schools might be using Games in class, but using them out of class is another step which is perhaps less common. Regarding Games, we anticipate that teachers might wish to ask us to give examples of or recommend suitable serious games for education. One Game did stand out as being widely used and also subject to several positive evaluations - Quest Atlantis (https://en.wikipedia.org/wiki/Quest_Atlantis - also see Amazon and YouTube). However, this Game is quite complicated and requires teacher time to get used to seeing how the game

works. This highlights a tension – simple Games might be discarded by teachers as being insufficiently educational, while complex Games might be discarded if teachers cannot find the time to learn them. However, this analysis is perhaps too naïve – if teachers can recognise the inherent educational value in either serious or commercial games of any complexity, they should be motivated to innovate.

Regarding the sub-group analysis, this nevertheless shows that digital technology is widely applicable, not just to all children, but also to special groups such as those with socio-economic disadvantage, low ability, disabilities, ethnic minority status, in rural schools, hospitalised or sick, and gifted. For teachers, the message is that digital technology is not just for the average or above-average student in a normal educational situation.

Further, 329 studies (24% of the total) took place outside the native English-speaking world, in 59 separate countries. The authors of these papers are to be congratulated on successfully publishing a paper in their second or subsequent language, but the numbers also indicate that digital technology is widely used outside the native English-speaking world, including in situations which seem at first sight deeply unpromising. Additionally, the high effectiveness demonstrated in these papers suggests that non-English native speakers succeed in obtaining good outcomes, although it may be that they publish in outlets which have less rigorous peer review.

We believe this paper is wider and more thorough than many reviews or meta-analyses in this area and has uncovered some issues not evident from the previous literature.

Implications for Future Practice, Policy and Research

Practice: This paper has been written primarily for teachers (many of whom will doubtless be content with their Executive Summary, perhaps accompanied by dipping into other sections as they feel the need). As children return to school full-time, we hope that teacher's experience of online and blended learning acquired during the lockdowns and school closures will be used productively as schools move forward. Even though marshalled at high speed without the benefit of much planning time, these innovations do indicate a new way of working for schools. Post-pandemic, while wholly online learning is probably not relevant for most pupils except those in remote areas, blended learning certainly offers promise. A system of accessing learning at home or in the public library during the morning with activities and discussion relating to that learning at school in the afternoon is certainly one schools might wish to experiment with. This could also help to increase engagement and performance in homework activities and support young people on study leave preparing for exams. Managing disadvantaged or procrastinating pupils might involve requiring them to attend school fulltime to use the computer facilities in schools (but not be fulltime in the classroom). Further teaching points are available in Appendix B.

Policy: Local and national government needs to develop local and national policies for online and particularly blended learning from schools. Governmental thinking needs to be better informed by the research base, and we hope that the availability of this paper (for instance) will be of help to government. is not sufficiently informed by the evidence base. It may be that teacher unions will be concerned by the suggested shift in teacher practice, but there is no

suggestion that fewer teachers will be needed; if anything, more (but better trained) teachers will be needed.

Research: This analysis of 1355 full papers proved to be time-consuming, but we would urge that future attempts to investigate these areas take the trouble to encompass all five areas, since they are obviously interlinked. Our definitions and coding system have proved reliable and future research may seek to adopt them. Equally obviously, this systematic review will need updating as time goes by. We hope that future research will take a broad perspective and acknowledge the difficulties we have encountered in undertaking this review and seek to find ways of resolving them. The heterogeneity of Effect Sizes and their lack of attribution to specific school sectors is an example of such a difficulty.

Conclusions

Overall, 85% of studies showed positive effects and only 3% found it worse. Blended Learning was more effective than Online Learning, although both were effective but to different degrees, and Online Learning may be the only option for students remote from school and those unable to attend school owing to pandemics or other causes. CAI was more effective than either, but much of CAI was in school, and it cannot be assumed that it would be as effective if delivered to homes. The effectiveness of Games and CSCL fell somewhere between Blended and Online Learning, but again much of this was in school, and it cannot be assumed that it would be as effective if delivered elsewhere. In relation to the Research Questions:

1. Do online and blended learning from schools have positive/negative/similar effects compared to traditional classroom teaching or digital learning in school? The answer is Positive for both Online and Blended Learning, but Blended Learning seems more effective than Online Learning.
2. Do Educational Games and Computer-Supported Collaborative Learning have positive/negative/similar effects compared to traditional classroom teaching or digital learning in school? The answer is Positive for both, although the evidence for Games is more persuasive than the evidence for CSCL.
3. Are the effects different between primary/elementary schools, middle schools and secondary/high schools? Primary and Early Years/Kindergarten show the most positive effects, followed by Secondary/High schools. Middle schools do not seem as effective. Science and Maths are the most popular subjects, but many other subjects are learned in this way. In addition, digital learning which was carried out in schools was categorised under Computer Assisted Instruction (CAI), which was also found to be effective, indeed the most effective of all five interventions, and clearly has the potential to be used outside of school.
4. Are the effects different in different subjects? A wide range of subjects shows positive results, not only Reading, Maths and Science/STEM, but also English, Writing, English as Foreign Language, Critical Thinking, Humanities, Art and Music, and Health. Effectiveness was not related to number of studies.
5. Are the effects different by gender? They are, and girls generally do better than boys.
6. Are the effects different for different sub-groups of students? Studies of "low ability" (HiLo) students and Second Language Learner (SLL) (mainly EFL learners) showed high levels of performance, greater than all studies combined. Studies of Rural students and

Hospitalised or Sick at Home students showed equal effectiveness to all studies combined. Disadvantaged and Gifted studies showed effects slightly lower than was average for all studies. Students with SEN or Disability showed effects slightly lower than was average for all studies. Studies of Deaf and Hard of Hearing, Down Syndrome, Writing Difficulty, ADHD, and ASD students showed greater effectiveness than was average for all students. Studies of Ethnic Minority students gave overall similar results. Students in Non-English-Speaking Educational Contexts (NESEC) showed high effectiveness (well above the average for all students), even though the 59 countries they lived in might have had cultural issues particular to digital learning.

7. Are the effects on Socio-Emotional Functioning (SEF) and Psychological Wellbeing (PWB) positive/negative/similar compared to being in school full-time? SEF studies (mostly focused on self-efficacy) showed high effectiveness, 91% Better than Traditional Instruction. PWB studies were much fewer and 79% noted an improvement.
8. What is the evidence for design principles or underlying digital pedagogies in any of these studies? There is a great deal of evidence on these areas which is summarised in Appendix A.
9. What teaching points for effective online/blended learning can be drawn from evidence-based studies? There is a great deal of evidence on these areas which is summarised in Appendix B.

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Appendix A – Design and Pedagogy Pointers from the Research Literature

Numbering is intended to facilitate access – it does not imply ranking in importance

Online Learning

1. Disasters lead to more online learning (e.g., hurricanes in the US) (c.f. covid-19)
2. The 2003 SARS outbreak in China led to the government encouraging online learning
3. Inter-school tutoring/mentoring in disasters – safe high to unsafe elementary school
4. Lack of social information/connectedness (esp. non-verbal behaviour) is a problem
5. If no computer at home, kids can come to school to use
6. Lack of social presence and cultural inclusion lowers effectiveness
7. In US, completely virtual schools operated in 26 states in 2013
8. Four states had online graduation requirements in 2013
9. Online learning can be presentational or interactive
10. Interactive = bulletin board, chat room, collaborative writing - balance needed
11. Embed metacognitive guidance/prompts
12. Match newer students with more experienced students (classes not relevant online)
13. Allow a proportion of working alone if requested by students
14. Synchronous is better than asynchronous, or...
15. Asynchronous is better than synchronous ...
16. (Probably both good but not for same purpose)
17. Self-regulation and motivation are very important
18. A teachable agent not found to raise effectiveness
19. Navigability, ease of use and interactivity are important
20. Differentiated learning options should be available for a degree of student choice
21. Volunteer tutors can include undergraduates
22. Volunteer tutors can include preservice teachers – cybermentoring
23. Using videoconferencing software raises effectiveness
24. Videoconferencing enables tutor to see level of concentration of students
25. Small groups of students can meet online with an experienced tutor
26. Virtual reality can be incorporated – with virtual manipulatives and peer interaction
27. A personalised recording system is effective in raising performance
28. A self-assessment tool raises effectiveness
29. Procrastination can be a big problem – a failure in self-regulation
30. Procrastination – cognitive behaviour therapy best of 4 interventions
31. Drop-out can be a problem – have algorithm to predict
32. Attention monitoring and Alarm Mechanism is effective
33. Inattention and fatigue measuring system can alert student if concentration wanders
34. Wording in math problems – little evidence different types effective
35. Problem-example vs. example-problem makes no difference
36. An annotation-based system creates effective sharing
37. Online learning can deliver safety and security education
38. Online learning very useful for school refusers (because of bullying and other reasons)
39. Online Tournaments can create a sense of challenge (but different levels needed)
40. Small rural schools can act as base for online students to give a sense of connection
41. Do not apply principles relevant to adults to children

42. "Big data" can synthesize outcomes leading to better conclusions
43. Longitudinal/follow-up research very much needed.

Blended Learning

1. Template available for organization of a flipped class
2. Lo et al. (2017) reviews design principles
3. Alonso et al. (2005) has a psycho-pedagogical instructional model
4. Blended learning has many different forms
5. Firewalls and security restrictions in schools may hamper online learning
6. There will be a significant start-up effort
7. FCTS software measures readiness of teacher/students for blended learning
8. Training improves outcomes
9. Digital work before class leading to discussion in class works best
10. Incorporate questions to promote student discussion
11. Interaction is fundamental – but varies greatly in quality
12. Require reflection on student understanding
13. Engineered flipped works better than just video + discussion (3 studies)
14. Mobile learning on field trips – enquiry into environment outside is effective
15. Mobile learning on field trips - need worksheets to scaffold
16. Mobile learning on field trips – need guides, scaffolds, supplementary materials
17. Mobile learning outside – have butterfly watching app
18. Mobile learning for EFL – listening, speaking practice effective – also at home
19. Mobile learning for EFL – can take mobile home
20. Mobile learning for EFL – more fun, maintains interest
21. Mobile learning – rural students benefit more
22. Mobile Learning – delivers extra information, enables student sharing, more effective
23. Mobile learning – need adapt to individual and gender
24. Pre-learning prior to flipping increases effectiveness
25. Digital learning leads to more active learners and less passivity
26. Concept mapping useful in mobile learning
27. Scaffolded problem-posing can lead to improved achievement and self-efficacy
28. Meta-cognitive scaffolding for web search is effective
29. Blended better than traditional methods for low ability math students
30. Simulation in science both visual and interactive heightens learning outcomes
31. Interactive video lectures at home are effective, but...
32. Video activities are better than video alone
33. Virtual peer models can demonstrate effectiveness at questioning in reading
34. Dialogue with teacher and peers – students can be facilitators
35. Need improve argumentative reasoning – more effective
36. Need improve diagrammatic argumentation – more effective
37. E-books successful in maths, esp. for low ability
38. Station rotation model – mixed results in effectiveness
39. Virtual laboratories in science can be effective
40. Very high cognitive load will reduce effectiveness
41. Low achieving pupils gain most
42. Liking not same as effectiveness – some time liking low but effectiveness high
43. Self-regulation prompts increase effectiveness
44. Self-efficacy leads to increased effectiveness
45. Adaptive e-learning responding to the needs of each student is most effective

46. Intelligent tutors can be effective but not well linked to curriculum
47. 60% of blended learning more effective than 20%
48. Anonymous peer assessment more effective
49. Online homework more effective than traditional homework
50. Online homework more effective than traditional homework esp. for at-risk students
51. Children sick at home can get short-term interventions which are effective
52. Blended learning for sexual health leads to increased knowledge, but ? behaviour
53. First Aid can be taught through blended learning
54. Blended learning works for students with learning difficulties
55. Twitter can be used and is effective but ? management of it
56. A coherent record-keeping system is needed
57. Kinaesthetic methods have no evidence to support them
58. Can link rural and urban schools – effective for rural schools
59. Parents often not on board, not invited or engaged
60. Blended learning can work for the most under-privileged in developing countries
61. Blended learning enables international collaboration
62. Need consistent leadership to heighten teacher confidence
63. An iterative phased roll-out of implementation should be planned.

Games

1. Games show big effects for cognition, but almost as big for affect
2. Games do not have much effect on behaviour, however
3. Games can be used outdoors as well as indoors
4. Games need connecting to the school curriculum (2 studies)
5. Games offer experience-based learning
6. Boredom and confusion are signs games not working (true of other instruction)
7. Games improve attention skills - but does this generalise?
8. Cognitive, motivational, affective and sociocultural issues all need addressing
9. Games can be played individually or collectively, but...
10. Peers outperform individuals, whether competitively or collaboratively (2 studies)
11. Both collaborative and competitive games lead to improved performance, but...
12. Collaborative games more effective than competitive games
13. Simulation in games very effective, esp. with active engagement
14. Even very disadvantaged children with no previous experience can use games
15. Very different cultural contexts mean some games don't fit
16. Teacher experience and style makes a difference (2 studies)
17. A Taxonomy of Games has been developed (de Lope et al., 2017)
18. Guide for Teachers on Selecting Games (Southgate et al., 2017)
19. Ease of use is important in effectiveness
20. Challenge is important in effectiveness (in relation to ZPD) (2 studies)
21. Degree of student control is important to effectiveness (5 studies)
22. Interactivity is important in effectiveness
23. Peer interactions need to be goal-oriented and purposeful
24. Goal-orientation is important in effectiveness
25. Goal-setting lowers cognitive load and yields more fun
26. Engagement is important in effectiveness
27. Scaffolding is important in effectiveness
28. Scaffolding reduces "stuckness"
29. Metacognition is important in effectiveness
30. Feedback is important in effectiveness
31. Intrinsic motivation more powerful than game rewards
32. Self-explanation can be effective if children respond to prompts
33. Self-efficacy very important at start (2 studies), then importance declines
34. Games with a Teachable Agent (avatar) no more effective than those without, but...
35. Games with a Teachable Agent more effective than those without (3 studies)
36. Concept Maps effective in raising performance
37. Role playing not effective
38. Concept Maps used effectively in EFL – grammar concept mapping (2 studies), but...
39. Not found effective elsewhere, whether student's or teacher's
40. Give background information rather than short-term advice for long-term effects
41. Learning Styles (sequential or global) - fitting game to LS increases effectiveness, but...
42. Matching game to Learning Styles made no difference (2 studies)
43. Field-Independent students achieve better than Field-Dependent students
44. Low ability students make bigger gains
45. Game before instruction better than instruction before game

46. More experience in game leads to more socialisation
47. Context needs to be set before game in social studies - active students learn more
48. Thinking Aloud and Modelling more effective than writing
49. 3-D games are more effective than 2-D games (2 studies)
50. Popularity of a game is not necessarily equal to its effectiveness, and...
51. Highly motivating games do not necessarily teach anything useful
52. Augmented Reality (AR) can increase enjoyment and curiosity, improve socialisation
53. Collaborative versions of AR work best
54. AR can help link game to real world
55. Some learning anxiety need with AR
56. More student control with AR better
57. Virtual Reality can lead to higher motivation
58. Non-competition group did better than competition group
59. Anonymous vs. non-anonymous competition both same and both effective
60. With competitive games, need same-ability matching, or less able students do worse
61. "Racing" game for argumentation increased speed but not quality
62. Badges and leader-board ranking improved effectiveness (but desirable?)
63. Computer maths drill game had no effect
64. Drill and practice in Writing game had weak effect
65. A grid-based "MindTool" available to structure sharing
66. Games in groups of 12 as effective as in pairs
67. EFL vocabulary learners – Watchers gained as much as Players
68. Games played in presence of an audience more effective than otherwise
69. Background music increases effectiveness (even though it appears distracting)
70. "Maths Snacks" are example of very short game, can do several in one session
71. Different narrative elements are likely to be relevant to different genders, ages
72. Beware of games that are repetitive with no innovation
73. There are games for Mental Health (anxiety, depression)
74. Games can cultivate student well-being in a dynamic, enjoyable and playful way
75. There are games for Autism (but need to program for generalisation) (4 studies)
76. There are games for children with Learning Difficulties (2 studies)
77. There are games for children with ADHD (2 studies)
78. There are games to learn Sign Language
79. There are Motion-Sensing games for disabled children
80. There is a Privacy Literacy game which is effective
81. There are games in Relationships and Sex Education
82. Social games are helpful for hospitalised children, esp. those in isolation
83. The commercial game Minecraft can be useful
84. Difficult to extricate what transferable skills are learned from games
85. There are scoring systems in games that track and display progress
86. Overall evaluation is difficult as games very different
87. Game and learning analytics could lead to the development of algorithms
88. Experience with games and e.g. Facebook leads to higher computer knowledge, or...
89. Is it just higher confidence?
90. Playing more games at home associated with worse outcomes – but what games?
91. More exposure to violent games can lead to aggression (2 studies)
92. Competitive game play may lead to aggression

93. But prosocial games improve prosocial behaviour (2 studies)
94. Parental acceptance of games - 60% in favour
95. Game designers may be predominantly male – biasing effect?
96. Females like instructive games; males like entertaining, competitive games
97. Have girls design games – heightens effectiveness (5 studies)
98. Girl game designers might encourage STEM careers (2 studies)
99. Making games can be outside of school
100. Designing games can be more enjoyable than playing them (2 studies)
101. Involve end-users in design
102. Involve people with disability in design
103. There are few policies on the incorporation of games in schools.

Computer Supported Collaborative Learning (CSCL)

1. Communication and collaboration skills need to be taught
2. Off-task behaviour is common even in pairs – it needs scaffolding
3. Social challenges can and do occur in CSCL
4. Social Network Analysis can identify introverts who need more careful managing
5. GAGFS software uses social network analysis to suggest matching
6. Group formation – homogenous or heterogeneous better than random or self-selected
7. Group size – 3 struggle to reach consensus, 5 encourages social loafing, 4 probably best
8. Adding scaffolds in collaborative environments raises performance, but...
9. Attempts to scaffold collaboration can lead to worse collaboration – take care
10. Collaboration scripts can scaffold CSCL very effectively
11. There are also tools to scaffold involving contributor ratings and feedback
12. Graphical tools for scaffolding argumentation work better than text
13. Assignment of roles does not work so well
14. Moderation by an expert improves quality of discussion, but...
15. A 2-step flow of communication through opinion leaders may be better than teachers
16. Distributed leadership and mutual engagement are very important
17. Help-seeking in peer learning is important
18. Peer feedback is very important
19. There is a Peer Education Diagnostic Learning Environment (PEDALE)
20. Self-regulation important but there are different kinds
21. Some kinds of self-regulation more important at certain times
22. Individuals need to develop awareness of the learning processes of others, leading to...
23. Groups need to develop social shared regulation (not just self-regulation)
24. There are tools which enable visualization of individual contributions to group process
25. Cultural background can be extremely important – need to be aware
26. Synchronous/asynchronous equally effective but different advantages/disadvantages
27. Reciprocal synchronous peer tutoring is effective
28. The development of argumentation is important but must be based on evidence
29. Scaffolding should be provided for argumentation
30. Teacher guidance for argumentation (epistemic and interactive) improves performance
31. Assessing argumentation quality – tricky but effective
32. Effects of argumentation on domain knowledge very small
33. Cooperative learning better for writing development
34. Video conferencing very effective with shared online workspaces, but...
35. Structured interaction better than just discussing video
36. Concept maps can be useful in CSCL in pairs
37. Wikis are useful for CSCL
38. In Wikis, teacher intervention should be dialogic, not directive
39. Digital storytelling can be very effective
40. Collaborative drawing can use shared canvases and scripted discourse
41. Animated graphics more effective than static graphics
42. Robots for dialogic discussion can be incorporated in CSCL...
43. Including a robot helper for pre-schoolers to learn words
44. Multi-touch tabletops more effective than individual computers for CSCL
45. Larger effects noted in science and engineering courses

- 46. CSCL in reading more effective than face-to-face
- 47. With CSCL in class, physical layout is a problem
- 48. Social and Emotional Learning can be supported at home via CSCL
- 49. More interactivity between teachers from different countries needed
- 50. Facebook and Twitter used to obtain “information” – “facts” need checking.

Computer Assisted Instruction (CAI)

1. Laptops to Ethiopia led to children improving in reasoning
2. Use of technology makes classroom more child-centred, not teacher-centred
3. Web-based instruction in class more effective than teacher-based instruction, but...
4. Comparing Face-to-Face and Internet collaboration, FtF is best
5. Teachers with poor skills, little experience and advanced age least likely to participate
6. Implementation has Entry, Adoption, and Adaptation phases – later is better
7. Systematic instructional design pays off
8. Pedagogically Meaningful Learning Questionnaire explores extent of learner control
9. Goal orientation, perceived added value, motivation, flexibility and feedback important
10. Increased engagement esp. of multiple modalities important
11. Individualised instruction is more effective than standard instruction
12. Social interaction outperforms presentation and students more satisfied
13. Concept mapping in organising web searches reduces cognitive load
14. Concept maps support reading comprehension effectiveness
15. Aim for flexibility as well as fluency
16. Spread out steps in learning to lower cognitive load and make diagnosis of error easier
17. Asynchronous discussion more effective than synchronous
18. Can have whole class contributing notes on interactive whiteboard
19. Interactive whiteboards useful for small group activity
20. Purported “salience” has little effect on achievement
21. Automatic personalisation has no effect
22. CSCL can be done in class with scripts
23. Improving motivation is crucial for effectiveness
24. High levels of engagement lead to better performance
25. Text-based and image-based feedback show no difference in effectiveness, but...
26. Words + graphics are always more effective than just words
27. Framework for creative writing increased creativity
28. Life-like multimedia materials increase effectiveness
29. Dynamic visualisations more effective than static visualisations
30. Metacognitive scaffolding very important
31. Scaffolds should be visual, spoken and text for higher effectiveness
32. Self-regulation very important
33. Problem-based learning requires more self-regulation
34. Thinking skills relevant to curriculum can be improved
35. Discourse can involve questions, explanations and social acknowledgement
36. Self-efficacy increases as metacognitive awareness increases
37. Procrastination increases as metacognitive ability declines
38. Poor general time-use habits lead to procrastination
39. Heighten awareness of attention to video lectures by measuring brainwaves
40. Matching pedagogical agent to gender of learner yields better effects
41. Spatial contiguity enhances effectiveness, esp. in low ability students
42. Use cognitive conflict to diagnose misconceptions
43. Greater student control heightens effectiveness
44. Fuzzy expert system can recommend options for learning
45. Digital notepad with prompts had no effect

46. Haptic software (haptic joystick) was effective
47. 3-D pens were effective
48. Podcasts are effective for vocabulary instruction
49. Digital story-telling is effective in raising performance
50. An Online Transition Curriculum in reading is effective
51. Computerised Elaborated Feedback is effective
52. E-readers make no significant difference to reading skills
53. Paper books more effective than e-readers (? habituation to e-readers)
54. Virtual reading coach focusing on basic skills increases fluency
55. Focus on Word Automatization led to transfer to more complex word types
56. Reading annotation system leads to discussion and raises effectiveness
57. E-portfolios improve writing skills and metacognition
58. E-portfolios improve writing with peer feedback
59. Multi-media simulation leads to higher cognitive load but better learning
60. Use Virtual Reality esp. in astronomy
61. Caricature animation increases effectiveness
62. Schema development strategies improve critical thinking
63. Multi-media perception tasks can improve attention
64. Matching to Learning Styles makes no difference
65. Wearable Technologies may be useful in CAI in classrooms and outside
66. Intelligent Tutor systems give metacognitive feedback on errors with lasting effects
67. Scaffolding in the design of experiments heightens effectiveness
68. Using Question Stems to scaffold response can be effective
69. Student question generation improves effectiveness
70. Developing productive questioning heightens effectiveness
71. Matching groups needs care – consider selection and rotation
72. Augmentation of curriculum with mobile devices better than substitution
73. Virtual Reality and Augmented Reality not the same – check definitions
74. Virtual Reality can be beneficial, but only with prior familiarisation
75. Elaborated feedback is more effective than simple feedback
76. Manage help-seeking behaviour in relation to challenge – too much is not effective
77. Scaffold students to develop assessment criteria for Art & Design – effective
78. Mobile tool for problem-based estimation in classroom heightens metacognition
79. Link to existing games, e.g. Monopoly – incorrect answer leads to remedial instruction
80. Dynamic Assessment possible (with GPAM-WATA) possible and effective
81. Dynamic Assessment by computer as good as that by teacher
82. Learning Assessment Tool gives feedback and reinforcement
83. Interactive Assessment (e.g. drag & drop) – different methods for different purposes?
84. Females might have different game preferences to males (teachers and students)
85. Caring for a virtual pet increases empathy, esp. for females
86. Anti-bullying software exists but no evidence
87. CAI for children with learning disabilities is effective and heightens social inclusion
88. SEN students show higher gains
89. There is CAI for Attention Deficit and Hyperactivity Disorder, but no evidence
90. Have rural and urban schools linked – My Buddy School scheme
91. Need to bridge school-society gap
92. External support needed to increase teacher confidence

- 93. Need teacher continuing professional development which is effective – could be online
- 94. Data-Driven Learning is effective – but what is it?
- 95. More parental support needed, not less – a problem in some homes.

Appendix B – Teaching Points from the Research Literature

The teaching points below are divided into those which are general to all digital technology, and those which are specific to each category of digital technology: Online Learning, Blended Learning, Games, CSCL and CAI. Readers should bear in mind that while Online Learning and Digital Technology teaching points are specifically focused on the use of these technologies out of school, in most cases teaching points for Games, CSCL and CAI are focused on the use of these technologies in school, and will need further thought if these technologies are to be used out of school.

Additionally, we found that some papers made recommendations without offering any data or evidence to support them (such papers were generally excluded from this review), some papers included data or evidence but made at least some recommendations which did not follow logically from the evidence (we excluded these recommendations), while some included data and evidence and made recommendations which did flow logically from the data and evidence presented (we only included these recommendations).

Thirdly, we were conscious that the number of recommendations in the Design Appendix A was rather large and that teachers were unlikely to have time to absorb and reflect on such a large number of recommendations. Consequently, we tried to prioritise the Appendix B recommendations in order of importance and only included 20-30 or so in each category, to make the processing burden for teachers more manageable.

General points are given first, with specialist sections following. Readers may wish to look at these General points first then the specialist section of their interest. If they have time, they may then want to read some of the other sections, as sometimes points are made in one section which could equally apply to other sections.

Numbering is intended to facilitate access – it does not imply ranking in importance.

General Points

Learning new skills or developing existing skills - educators

1. Whether you are expert or not, investigating and delivering new software in new contexts always takes a lot of time. Be patient with yourself and notice the improvements you are making. New learning can be energising but also be anxiety provoking at times. This investigation and delivery never stops – it is a journey that is endless. Trying to do anything quickly is very difficult.
2. Given the shift in methods of teaching the pandemic brought, many teachers will feel the need for continuing professional development in this area. Spend time on this, either informally with colleagues in your own or other schools or via interest networks on the Web, or formally via CPD programmes from your own local authority/school district or from national organisations via webinars. When sourcing training be sure that there is some kind of follow-up to enable you to raise questions and difficulties once you are back in your own classroom, either one-to-one or via a follow-up web group.
3. Informal peer support networks are invaluable ways of finding solutions to challenges. Talk about how you can set these up within your school and district.

Software, safety and security

4. You may find that your school district/local authority have strict rules and complex firewalls about the software you can use in school. However, they do not of course have any control over computers, tablets and mobiles that students have access to outside of school. So, you might prefer to recommend software to students for use out of school.
5. Safety and security: Create awareness of cyber-malice and ensure security interventions against unethical learning practices, academic dishonesty, identity theft and bullying are in place.
6. One of the barriers to widespread use of software is cost. Your school may decide to invest in a few programmes which most or all teachers might use. Beyond this, you might need to access freeware (software with no cost) – try putting for example “Educational Games freeware” (with the inverted commas) into Google and see what comes out. A problem here is that freeware is almost always simpler than bought software, so experienced computer adherents among your students might regard it as too crude.
7. Consider what hardware your students have access to outside of school. PC or Apple computer? Apple or PC or Android tablet? Game consoles – Xbox, PlayStation, Wii,

Nintendo, other? Handheld or static? Apple or Android mobile phone? Regarding mobile phones, is the contract pay-as-you-go, limited data or unlimited data? (This will determine whether the students can use the internet or only download software to use off-line, as cost will be an issue.) Their own or shared with the family? If the latter, how big is the family? Is there internet access? Download/upload speed slow/medium/fast? If not at home, perhaps at library or elsewhere? Take a confidential class survey to see what hardware your software will need to function with, and identify students who have limited or no access.

8. Remember most children will have developed their computer skills outside of school, and may be very sophisticated in a limited number of softwares but not at all capable with other softwares not in their experience.

Selection of software

9. Ensure software is appropriate for gender and cultural context.
10. Consider the curriculum and what objectives you would set for the use of the software. Does the software have a story and a mission? Is humour used? Think about what pedagogical principles will apply to the use of the software – how will it be delivered, what will pupils learn, how will they learn, what support will they need from the teacher and what support from peers? Do not try to deliver traditional classroom instruction via technology – it won't work. You need to reconceptualize the pedagogical opportunities afforded by technology.
11. Your software should be capable of operation at several levels of difficulty (low floor, high ceiling), to allow for differentiation between students in the class. Have your students set their own goals to improve their level. Some software can set challenge levels depending on the players' skills and performance and adjust up and down. Do not assume that students who appear of lower ability and/or peer self-discipline in class will be of lower ability in the digital environment.
12. Your software should require students to react and interact, either with tasks within the software or with peers and preferably both, or even with the teacher. Try using blogs, wikis (i.e., a website that allows users to add and update content) and shared e-portfolios (i.e., student owned digital workspaces where they can capture ideas, share their learning, set goals, store finished work and items they are working on, etc.) to encourage online sharing.
13. Your software should embed prompts, cues and scaffolding to guide students to succeed.

14. Try to use software incorporating multiple modalities – including visual, auditory, written; static and dynamic.

Improving learning through delivery

15. Incorporate questions and require reflection to promote student discussion. Try to improve the quality of student questioning to facilitate discussion and elicit more elaborate answers. Use more penetrating questions, (hopefully) to get more elaborate answers.
16. Try diagrammatic argumentation (having pupils explain a logical argument by way of a drawing) and other graphical tools. Concept mapping can be useful instead of more conventional linear writing and can promote immediate sharing and discussion.

Explicit teaching of communication and collaboration skills

17. Teach communication and collaboration skills – have (a small number of) rules to remind students (preferably negotiated with them).
18. Student self-confidence (self-efficacy) is very important, especially on initial exposure to new software – take care to nurture it. Providing targeted feedback will increase pupil confidence and perseverance. Also manage your own self-efficacy, which will show the same pattern.
19. More student control is generally better (teachers sometimes have difficulty letting go of control). Is there a shared purpose and openly networked infrastructures?

Student engagement

20. Monitor degree of student engagement and amount of feedback from teacher, peers and elsewhere. These are important to sustain interest.
21. Ensure the quantity of work is appropriate for the students age and stage of development. Don't dishearten students early on with unmanageable work demands.
22. Let students be aware of problems of inattention and fatigue in advance. Failure to complete tasks by deadline (procrastination) predicts dropout – if students are struggling, get them to contact you and check the level of task with which they are struggling. Video-conference if you need to. If they won't contact you, try to get a peer to contact them.

23. Match up peers in small buddy groups or pairs so they can keep an eye on each other as well as working together. Similarly, try to match up more and less expert teachers in mentoring pairs or small groups to help each other. Similarly, try to match up schools – primary with high, disaster school with non-disaster school, rural with urban, schools in different countries, pre-service teachers with students, and so forth.
24. Encourage students to take breaks and have short periods of exercise and fresh air (where possible).
25. Use peer models (perhaps from older classes) to demonstrate how to perform skills or think aloud in any subject.
26. Consider building in forms of peer assessment and self-assessment, to help promote meta-cognitive skills (Metacognition is thinking about one's thinking. More precisely, it refers to the processes used to plan, monitor, and assess one's understanding and performance).
27. Try encouraging students to communicate outside of school via Facebook, Twitter, WhatsApp or other means more familiar to them. However, when Facebook and Twitter are used to obtain “information”, the “facts” need checking.
28. Do not confuse popularity or ease of use with effectiveness. Popularity may be good to start, but soon effectiveness will be required.
29. At the end of each session, foreshadow the next session, give any additional (homework) tasks, praise the students and say au revoir (until the next time).

Parents

30. Communicate clearly to parents what you hope they will be able to do by way of support at home. Give them some route to contact you with questions and concerns

Financial implications

31. Remember that both parents and schools may be incurring higher internet bills.

Online Learning Points

Definition

Online Learning is a style of education in which students learn complete programmes of work only via electronic and online media, so that they can completely control the time, pace, and place of their learning (Oxford English Dictionary).

1. There have always been disasters somewhere in the world and countries regularly turn to online learning.
2. If there is no computer available at home, kids could go to school or library to use, but more difficult if remote from either.

Social connectedness / working with others

3. Build social connectedness through online activities before expecting too much academically.
4. Students from schools can be linked (e.g., primary to high) to help raise morale.
5. Match up peers in buddy pairs or small groups, perhaps older with younger, more able with less able, newer with more experienced students.
6. Allow a proportion of working alone, especially if requested by students.
7. Synchronous working (i.e., working together at the same time, as in chat rooms for example) gives better social connectedness, asynchronous is more convenient. Try to mix the two
8. Video use is particularly important for slow learners because they can pause, rewind or fast forward the video, and can watch the online videos again and again until they have mastered the lesson content

Engagement and high-quality on-line learning

9. Make online learning interactive (e.g., via bulletin boards, chat rooms, collaborative writing) as much as presentational – do not try to replicate traditional class instruction online.
10. Online learning enables the embedding of prompts or cues to guide students and promote metacognition.

11. Ease of use, navigability, and interactivity are important. Software should be amenable to use at different levels of ability. Harder software will need support or students will give up.
12. Videoconferencing software with individuals or a class improves social connectedness and motivation – and also enables the teacher or tutor to see levels of concentration.
13. Virtual reality can be incorporated if you have the skills and software – with virtual manipulatives and peer interaction.
14. Online tournaments can create a sense of challenge (but take time to organise and different levels are needed).

Consideration of social /emotional factors

15. Procrastination can be a big problem and predicts dropout – alert students to the dangers.
16. Encourage students to be aware of/measure inattention and fatigue and report to teacher for discussion if needed.
17. If possible, deploy volunteer tutors (undergraduates, preservice teachers, senior students).
18. Consider a personalised recording system, self-assessment to maintain time on task for both parties.
19. A group mutually annotating one document or drawing (e.g., in Google Docs or Office 365) creates effective sharing.

Blended Learning Points

Definition

Blended Learning is a style of education in which students learn via electronic and online media as well as traditional face-to-face teaching in the classroom, so that they can, in part, control the time, pace, and place of their learning (Oxford English Dictionary).

Student and teacher readiness

1. You might want to use the Flipped Classroom Teacher Scale (FCTS) software to measure the readiness of teacher/students for blended learning.
2. Try to obtain some training yourself and give the students some training.

Blending digital work and face to face

3. Digital work before class leading to discussion in class works best, preferably on the same day so students don't forget.
4. Expect 50% of learning outside school and 50% inside school as a general guide.

Creating learning dialogues

5. Incorporate questions and require reflection to promote student discussion.
6. Think about how to improve argumentative reasoning among students, so they ask each other more penetrating questions, (hopefully) get more elaborate answers and become more able to improve diagrammatic argumentation.
7. Concept mapping can be useful rather than more conventional writing and can promote immediate sharing and discussion.
8. Collaborative problem solution can likewise promote sharing and discussion.
9. You could try encouraging student pairs or groups to communicate outside school on learning topics via Facebook, Twitter, WhatsApp or other means with which they are more familiar.
10. Linking rural and urban schools is effective for rural schools.
11. Blended learning can enable international collaboration between schools, e.g., in learning Foreign Languages.

Mobile Learning

12. Mobile learning can be effective on (virtual?) field trips, with electronic worksheets to scaffold.
13. Mobile learning is good for English as a Foreign Language listening and speaking practice effective, especially if students connected to converse.
14. Mobile learning – like all learning experiences mobile learning should be adapted to individual and gender needs.

Using video footage/virtual peer models

15. Shorter videos are usually better than longer videos.
16. Simulation in science (visual, auditory and interactive) can replace laboratory experiments.
17. Interactive video should lead to activities designed to consolidate and extend learning.
18. Virtual peer models can demonstrate how to perform skills or think aloud (verbalise their thinking aloud) in any subject.

Matching learning experience to student's needs and abilities

19. Try to keep cognitive load (i.e., a student's information processing capacity and working memory resource within each students' capability – but remember that in a blended environment your estimates of student ability may be wrong.
20. Remember low achieving pupils usually gain most, provided they engage with the software.
21. Students with Special Needs, Additional Support Needs or Disability may need more support at first but can certainly benefit from Blended Learning.

Motivation, effectiveness and self-confidence

22. Liking is not same as effectiveness – sometimes liking is low but effectiveness high, and vice versa.
23. Student confidence (self-efficacy) is very important in positive outcomes. Have students expect to struggle at first but become confident as they become familiar.

24. Teacher confidence (self-efficacy) is also very important in positive outcomes. Observe your own confidence growing and celebrate it.
25. Blended Learning involves parents more, so communicate and be clear how you want them to help (if possible).
26. Subjects often viewed as not being at the core of the curriculum also can be taught through blended learning e.g., First Aid, Sexual and Relationship Education.

Computerised Educational Games Points

Definition

Computerised educational games are designed to help people learn about certain subjects, expand concepts, reinforce development, understand a historical event or culture, or assist them in learning a skill as they play, but do so within the context of a game which has rules and clear objectives (e.g., to “win”).

Range of computerised educational games available

1. There are many types of games, e.g., Action, Adventure, Animated Tutorial, Puzzle, Role-playing, Simulation, Sports, Strategy, Virtual reality, Virtual world, Games-based Construction Learning (Hailey, et al., 2016).

Selection of computerised educational games

2. Ensure the Game is appropriate for gender and cultural context.
3. Games typically have scoring systems that track and display progress.
4. Quality of a game is important – e.g., 3-D games more effective than 2-D games.
5. Augmented Reality (AR) (Augmented reality is an interactive experience of a real world environment where the objects in the real world are enhanced by computer generated information) can increase enjoyment, curiosity and motivation, help link the game to the real world, and improve socialisation (especially collaborative versions).

Effectiveness of computerised educational games

6. Ease of use, challenge, degree of student control, and interactivity are important in effectiveness.
7. The popularity of a game is not necessarily equal to its effectiveness.
8. More student control generally works better in the long run (teachers sometimes have difficulty letting go of control).
9. Collaborative games are more effective than competitive games.
10. Simulation in games is very effective, especially with active engagement.

11. Games can be played individually or collectively, but peers working together outperform individuals.
12. Goal-setting lowers cognitive load and yields more fun – including peer interactions.
13. Scaffolding and engagement are important, as in every learning task.
14. Provision of specific feedback and encouraging children to think about what strategies they use (metacognition) can improve learning.
15. Concept mapping (i.e., visual representations that student create to connect concepts, ideas, terms) is effective in raising performance.
16. Games with a Teachable Agent (avatar) tend to be more effective than those without.
17. Background music increases effectiveness (even though it appears distracting).
18. Prosocial games improve prosocial behaviour.

Pupil confidence

19. Self-efficacy (confidence) is very important at start as students are anxious, then importance declines.

Considerations for different groups of students

20. Designing games can be more enjoyable than playing them, especially for girls.
21. Females tend to like instructive games; males tend to like entertaining, competitive games.
22. With games, “Lower ability” students tend to make bigger gains than more average or above average students – because games are not like every day learning in school.
23. There are games for Autism, Learning Difficulties and Attention Deficit and Hyperactivity Disorder.

Generalising learning from games

24. Games promote interest and enjoyment, but are sometimes difficult to directly relate to the school curriculum.

25. Games can improve attention skills - but the research is less robust on the question of whether this generalises over time and to other activities.
26. Think about how you will follow up game use, encouraging the students to reflect on what has been learned and how it connects to the curriculum.

Computer Supported Collaborative Learning (CSCL) Points

Definition

Computer Supported Collaborative Learning (CSCL) concerns how collaborative learning supported by technology can enhance peer interaction and enable work in groups, and how collaboration and technology facilitate sharing and distributing of knowledge and expertise among community members (Lipponen, 2002).

General

1. Cultural background can be extremely important – teachers need to be aware of this.
2. Self-regulation is important to develop in pupils, Self-regulation can be emotional, behavioural or cognitive. Self-regulation strategies include: Self-monitoring or self-assessment or self-recording), Self-instruction (also called self-talk), Goal-setting, and Self-reinforcement. There are different kinds, important at different times.

Teaching of skills to enhance performance

3. Communication and collaboration skills need to be taught.
4. Individuals need to develop awareness of the learning processes of others, leading to metacognition.
5. The development of argumentation to enhance reasoning processes in pupils is important and must be scaffolded by the teacher and within peer group settings.

Group formation and collaborative working

6. Group formation – homogenous or heterogeneous better than random or self-selected.
7. Group size – 3 struggle to reach consensus, 5 encourages social loafing, 4 probably best.
8. Off-task behaviour is common even in pairs – scaffold to reduce/eliminate.
9. Peer feedback is very important. Educators may wish to model good examples and monitor feedback provided by peers?

Effective elements identified in research

10. Cooperative learning in writing development is more effective than solo writing.
11. Digital storytelling can be very effective.
12. Animated graphics are more effective than static graphics.
13. Video conferencing very effective with shared online workspaces.
14. Discussion after video watching better if structured.

Raising effectiveness of learning through games

15. Add scaffolds or suggested collaboration scripts or graphical tools to raise performance.
16. Concept maps can be useful (e.g., in helping students visually chunk or organize information into meaningful connections).
17. Wikis (with dialogue between peers rather than directive teacher input) are useful.
18. Collaborative drawing can use shared canvases and scripted discourse.
19. Robot helpers can facilitate scaffolding.

Use of social media to gather information

20. When Facebook and Twitter are used to obtain “information”, the “facts” need checking.

Computer Assisted Instruction (CAI) Points

Definition

Computer Assisted Instruction is an interactive instructional technique using a combination of text, graphics, sound and video whereby a computer is used to present a programme of instructional material, have the student interact with it, and monitor the learning that takes place. CAI programmes can be simply drill and practice, or they can be much more complex, e.g., involving simulations (WikiEducator).

Teacher engagement

1. Research suggests that teachers with poor skills, little experience and advanced age are least likely to participate, although of course there are exceptions. Staff development opportunities should be considered.

Strategies to increase effectiveness

2. Scaffolds should be visual, spoken and text for higher effectiveness in learning.
3. Words + graphics are always more effective than just words.
4. Dynamic visualisations of educational concepts (e.g., animations, interaction and realtime) are more effective ways of demonstrating educational concepts than static ones (e.g., static charts, maps)
5. Increased engagement especially with multiple modalities (e.g. the different ways in which learning is presented) is important.
6. Multi-media simulation leads to higher cognitive load but better learning.
7. Spread out steps in learning to lower cognitive load and make diagnosis and identification of student errors of error easier.
8. Concept mapping in organising web searches reduces cognitive load (i.e., a students' information processing capacity and working memory resource).
9. Specifically individualised instruction is more effective than standardised instruction.
10. Using Question Stems to scaffold response can be effective (Question Stems are the beginning of a question, leaving the pupil to complete it in any way they wish. Question Stems may relate to Knowledge and Comprehension, Application and Analysis, or Synthesis and Evaluation).

11. Providing temporary support to help students carry out a task (i.e., metacognitive scaffolding) remains as important in computer assisted learning as it is in face-to-face teaching.
12. Student question generation improves effectiveness.

Social interaction

13. Social interaction outperforms presentation and students are more satisfied.
14. Help to develop opportunities for whole classes or small groups to contribute to tasks e.g., add notes to a virtual interactive whiteboard.

Effective digital elements

15. Podcasts can be effective, especially for vocabulary instruction.
16. Digital story-telling is effective in raising performance.
17. A reading annotation system (i.e., markings that encourage interaction with the text, opportunities for highlighting, underlining, note making) leads to discussion and raises effectiveness.
18. E-portfolios (i.e., student owned digital workspaces where they can capture ideas, share their learning, set goals, store finished and incomplete work, etc.) improve writing skills and metacognition with peer feedback.
19. Caricature animation increases learning effectiveness.
20. Virtual Reality can be beneficial, but only with prior familiarisation.

Engagement, motivation and socio-emotional factors

21. Improved motivation and engagement lead to better performance.
22. Ensure learners have a significant degree of control - greater student control tends to heighten effectiveness. If you direct the pupils too much all the time you will stifle their creativity.
23. Caring for a virtual pet increases empathy, esp. for females.
24. Self-regulation is also very important, especially in problem-based learning.

25. Self-efficacy (self-confidence) increases as metacognitive awareness (being aware of how you think and the strategies you use) increases.

26. Procrastination increases as metacognitive ability declines.

Outside learning

27. Wearable Technologies may be useful in CAI outside.

Students with special educational needs, disability or additional support needs

28. CAI for children with SEN, Learning Disabilities is effective and heightens social inclusion.

Linking schools

29. Have rural and urban schools linked – My Buddy School scheme.

30. Goal orientation, pupil perceived added value, motivation, flexibility and feedback are important in enhancing effective learning.

31. Discourse between teacher and pupils and between peers can and should involve questions, explanations and social acknowledgement.

32. Manage help-seeking behaviour from pupils in relation to the amount of challenge – too much helping with tasks well within the pupils' ability is not effective.

33. Systematic instructional design tends to be more effective, but beware this does not lead your instruction to be too teacher-directed.

34. The gender of an avatar in digital technology will be more effective if it aligned with the gender of the pupil. The facility for the pupil to select avatars is helpful. Matching gender of pedagogical agent to gender of learner yields better effects.